THE ENGINEER

A Seven-Day Journal

Institute of Marine Engineers' Annual Dinner

Over a thousand marine engineers and their guests were received by the president of the Institute of Marine Engineers, Dr. S. F. Dorey, C.B.E., F.R.S., on the occasion of the forty-ninth annual dinner, which was held at Grosvenor House, Park Lane, London, on Friday, March 14th. After honouring the Loyal Toasts, His Excellency, Count Edouard Reventlow, G.C.V.O., the Danish Ambassador, proposed the toast of "The Royal and Merchant Navies of the British Commonwealth." He thanked the British Admiralty for the help given to Danish naval officers, and made several historical references to past associations and the present partnership in the North Atlantic alliance. In his reply, the Right Honourable J. P. L. Thomas, M.P., the First Lord of the Admiralty, mentioned the difficulties in building up the Navy, and the loss sustained by shipbuilding in the deaths of Sir Amos Ayre and Sir James Lithgow. After a brief reference to the co-operation between navies, he went on to discuss the healthy condition of shipbuilding and marine engineering, although hampered by the steel shortage, and hoped that supplies of American steel would help to ease the situation so that shipping could continue to contribute to the balance of payments. Mr. Thomas paid tribute to the research efforts of Pametrada and stressed the need to maintain our maritime prestige. In giving the toast of "The Institute of Marine Engineers," the Right Honourable J. S. Maclay, C.M.G., M.P., the Minister of Transport, had something to say about developments in marine engineering, the steadily rising membership of the Institute, and the wide field covered by the technical papers presented. Dr. S. F. Dorey, the president, in his reply, commented upon the success of the recently-formed local sections of the Institute, and went on to discuss the formation of a Royal College of Technology and the new training scheme for engineers. He also advocated the need to gain knowledge in other industries and the opportunity to apply new discoveries to the well-being of mankind. At the conclusion of his speech, Dr. Dorey announced that Mr. B. C. Curling, who retired from the secretaryship last year, had been elected an Honorary Member and presented him with his certificate. Mr. J. Turnbull, O.B.E., proposed the toast of "Our Guests," and Mr. T. F. Clarke replied.

Gas Industry Productivity Team

A productivity team from the gas industry has left this country for the United States, and will arrive back in Britain early in May. The sixteen members of this team have been selected by the Gas Council, in co-operation with the workers' side of the National Joint Industrial Council for the Gas Industry, and it is fully representative of all phases of production and distribution in the gas industry. The team leader is Mr. J. H. Dyde, and the joint secretary Mr. D. L. Hill. During its tour the team will visit the most modern gas plants and other installations in different parts of the United States. It will study the structure and organisation of the American gas industry, distribution techniques, industrial and commercial applications of gas, the utilisation of liquified and gaseous products, carbonisation and coke ovens, consumer services, industrial relations and training of personnel. It is hoped that the team will have the opportunity of taking part in conferences which the American Gas Association is holding at Philadelphia and Cincinnati during the time of its visit. It is probable that plants of special interest to the gas industry will be visited in the following areas: New York, Cleveland, Chicago, Portland (Oregon), Los Angeles, Birmingham (Alabama), Philadelphia, Pittsburgh, Cincinnati and Washington.

Building and Civil Engineering Exhibition at Glasgow

The Corporation of Glasgow has organised a building and civil engineering exhibition, which will be held at the Kelvin Hall from March 26th until April 12th. The exhibition is the first of its kind to be promoted by the corporation; it being thought that the time was opportune for the exhibition, in view of the importance of the building and civil engineering industries in the development of Scotland. About 140,000 people are employed in building and civil engineering in Scotland, and there are large numbers of people employed in the ancillary building material industries. The output of constructional and repair work represents nearly two-thirds of the country's fixed capital investment, and there is a heavy programme of work, comprising housing, schools and other building projects, industrial expansion, hydro-electric schemes, and the establishment of new towns at East Kilbride and Glenrothes. The corporation hopes to bring together a comprehensive display of the various aspects of the industry's work. The exhibitors include both private firms and departments of Government and public bodies connected with the industry. Constructional plant and materials will be exhibited, as well as displays of research work, and a section devoted to education and training.

Wind Power Generator for North Wales

The erection of a wind-driven power generator at Mynydd Anelog, Aberdaron, Caernarvonshire, has now received the formal consent of the Minister of Fuel and Power. We may recall that soon after the British Electricity Authority was established in 1948 it decided to associate itself directly with the research work on wind generation already being carried out by the British Electrical and Allied Industries Research Association (E.R.A.). In March, 1949, tenders were therefore invited for the design and construction of an experimental 100kW wind generator, and investigations began, in collaboration with the E.R.A., into wind conditions on the North Wales coast. In June, 1950, a contract was placed with Enfield Cables, Ltd., for a machine operating on a principle evolved by Monsieur J. Andreau; de Havilland Propellers, Ltd., is responsible for the aerodynamic performance and the English Electric Company, Ltd., for the alternator and control apparatus. The wind-driven propeller of the Enfield-Andreau generator is not connected by gearing to the turbine, as is usual in other windmill generators. There are two aluminium alloy propeller blades, of hollow construction with air exit ports at the tips, sweeping a circle of 80ft diameter. When the propeller rotates air is discharged from the blade tips by centrifugal force and suction is thereby created in the 100ft high hollow tower on which the propeller is mounted. Air is drawn through apertures in the base of this tower and, in its passage up the vertical shaft of the tower, drives a turbine. The controls of the generator are operated automatically by wind pressure on a speed-sensitive device. Electrical controls operate a valve when it is required that the indrawn air should by-pass the turbine in the support tower; thus, when this valve is open the turbine cannot operate although the propeller may be rotating. Hydraulic controls, similar to those developed for de Havilland aircraft, change the pitch of the blades of the propeller to suit various wind speeds, ensuring that the propeller turns at a constant speed of 100 r.p.m. When winds exceed 75 miles an hour, the blades are feathered and halted. An 8kW model of the "Anemo" machine, as the Enfield-Andreau generator is called, has been tested in France. The 100kW machine now being constructed for the Authority will be erected temporarily on a site near St. Albans within the next few months and, after undergoing operational tests extending throughout the winter of 1952–53, will probably be transferred to the permanent site on Mynydd Anelog in the spring of next year.

The "Princess" and "Brabazon" Aircraft

A written parliamentary reply, made on Monday last by the Minister of Supply, contained further reference to the development programme related to the "Brabazon" and "Princess" aircraft. It was stated that work upon the first "Princess" flying boat, now nearing completion, which is fitted with the MKII version of the Bristol "Proteus" propeller turbine engine, would continue so that flight testing could proceed. It had been decided, however, to postpone for the time being the work of completing the second and third "Princess" aircraft and the MKII version of the "Brabazon" machine, which were also to have had the MKII "Proteus" engine. The reply explained that this decision was taken, as it had become evident that great economy would be achieved by waiting for the production of the more powerful MKIII version of this engine, which was not yet available. As a result of this decision a saving of £2,000,000 would be effected in the coming financial year and at the same time would release capacity for more immediately required aircraft.

Liverpool Steam Ship Owners' Association

This week the Liverpool Steam Ship Owners' Association has issued its report for 1951, which forms a complete survey of the affairs of the shipping industry. External trade and the difficulties of maintaining exports are given particular attention, while it is stressed that the fortunes of the shipping industry and those of the nation are closely related. The report draws attention to the enormous depletion to reserves as a result of replacing the severe losses in tonnage sustained during two world wars and due also to the compensation paid for ships lost falling far short of the actual replacement cost. The continuation of the existing policy of taxation will make it impossible for the industry to replace any future losses by depriving it of essential resources. Stating that the principle of accountancy is to record fact and not one of management, the report urges that the effect of the inflation of the pound upon depreciation allowances is a matter requiring early examination. The report gives the amount of gross tonnage entered in the Association as 4,794,050 tons, the increase over the total at the beginning of 1951 being accounted for by the entry of new members. It is regretted, however, that full use of the tonnage available is not made, due to the serious delays in the turn round of ships, and instances of slow loading rates at world ports are given. The adverse effect of strikes, go-slow tactics and restrictive practices upon ultimate costs is emphasised and also the benefits accruing should pre-war handling rates at the ports be achieved.

Simplified Standards for Gears

By W. A. TUPLIN, D.Sc., M.I.Mech.E.*

Because a standard involute gear generating cutter can produce a wide variety of satisfactory tooth forms, it is reasonable to define a standard gear as one that may be generated by a standard cutter. It is desirable to use a simple system of gear design that permits full use to be made of the versatility of standard involute generating tools. Any calculation procedure that demands an accuracy beyond that offered by the 10in slide rule is not well conceived.

THE process of revising the British Standard Specifications on gearing repeatedly brings up the question of intelligibility to the average user. A life-long specialist in any subject does not fully appreciate the difficulty that a non-specialist may have in thoroughly understanding its accepted terminology and concepts. The specialist cannot easily see the need for avoiding specialised terminology in a publication intended for wide utility. He is loth to accept the suggestion that working rules for designers may often be presented in non-specialised terms if the specialist is prepared to suppress the jargon with which he has grown up, rather than to display it. He is inclined to resent any suggestion that his own ways of handling problems can be replaced by simpler ones after rational analysis directed towards development of non-specialist treatment.

Anyone who opens a text book on toothed gearing and glances through pages of geometrical drawings and trigonometrical expressions may well form the impression that the subject is of considerable academic interest and that a full comprehension of its technicalities may require some prolonged study. Anyone who sees gear-generating machines at work on commercial production of gears in endless variety may well doubt whether the design of ordinary gears necessarily involves any profound niceties in technology. Actually it does not, but those who for many years have been wont to calculate gear dimensions to half a dozen superficially significant figures with the aid of seven-figure mathematical tables and calculating machine are inclined to resent the suggestion that the same work can be done without those aids in a fraction of the time.

The production of a screw demands only the turning of a blank to a specified diameter and the sinking of a standard cutter in it to full depth, whilst blank and cutter are given predetermined relative motion by the machine used for the thread-cutting operation. This description also applies exactly to the production of a gear and so it is reasonable to enquire whether the determination of manufacturing dimensions can justifiably be much more complicated for one than for the other. The selection of a standard screw for a particular application demands no knowledge of the geometry of screw threads but merely an understanding of the terms "diameter" and "pitch." The suggestion that gear dimensions can be determined on the same limited basis may appear outrageous, until it is reflected that at one time gear design did involve no more than that. Later on it was made much more complicated by gear technologists who found in gear generating processes a fascinating basis for kinematic castles and towers of trigonometry which, having fulfilled their only possible purpose (that of aiding exploration of the field), may now be ignored by the gear designer and attention may be confined to simple design-procedure proved by practice. So the idea that a helical gear is determined by a blank-diameter, a standard cutter, and an axial pitch, is not a new one, but, on the contrary, the old and obvious one disentangled from complications that have outlasted any use that they may ever have had.

The general problem discussed here is that of determining the dimensions required before proceeding with manufacture of a pair of spur or helical gears. It is taken as axiomatic that no non-standard tools shall be required; it is assumed that the finished gears are to have a specified velocity ratio within a tolerance of about ± 3 per cent and are to work together with specified backlash at a specified centre distance. These conditions cannot, in general, be met by spur gears designed on what may be called the "Brown and Sharpe" system, because there the working centre distance of a pair of spur gears having t and T teeth of pitch p_n is $(p_n/2\pi)\ (t+T)$ with no more than normal machining tolerance. Involute gears cut by a generating process are not similarly restricted, but the common belief, warmly fostered by perusal of text books, is that any escape from that restriction involves troublesome calculation and there are those who therefore doubt whether such "non-standard" gears will work satisfactorily. This belief is quite unfounded and if the problem is examined from the purely practical standpoint (and the whole object of making gears at all is purely practical) there is no difficulty in devising a design procedure of the utmost simplicity that affords adequate flexibility and demands no calculation beyond the scope of normal slide-rule working. That this is possible is due to the inherent characteristics of the involute tooth form and of the generating principle.

It is convenient here to think in terms of the hobbing process, although the principles apply equally to any other gear-generating method. A gear cut by hobbing has the essential characteristics that:—

(*a*) The normal base pitch of its teeth is that of the teeth of the hob.

(*b*) The axial pitch of its teeth is that determined by the set-up of the "spiralling train" of the hobbing machine. (The formula for the set-up is often made to depend on the lead of the work and that is simply the product of axial pitch and number of teeth. In other cases the "formula" for the spiralling charge gears is made to look as if it depends on a spiral angle instead of on the fundamental quantity, axial pitch.)

(*c*) The diameter of the coaxial cylinder at which the tooth thickness is equal to half the tooth pitch depends on the dimensions of the hob and its centre distance from the work when taking the finishing cut.

The depth of tooth in each of the mating gears should be that for which the particular hob has been made. This, taken in conjunction with (*c*), shows that the blank diameter of the gear has some importance; it has, in fact, the first importance from the practical viewpoint, as it is required for the very first operation in machining the gear-blank.

Simplified Design Procedure

The meanings of the symbols used here are tabulated below. All length dimensions are in inches.

C = Centre distance of wheel and pinion
d_a = Tip diameter of pinion
D_a = Tip diameter of wheel
g = Thickness setting of caliper for pinion
G = Thickness setting of caliper for wheel
h = Height setting of caliper for pinion
H = Height setting of caliper for wheel
p_a = Axial pitch of pinion and wheel
p_n = Normal pitch of cutter, assumed to be of British Standard form, 20 deg. normal pressure angle
S = Diameter adjustment factor (see Fig. 1)
Suffixes p and w refer to pinion and wheel respectively
t = Number of teeth in pinion
T = Number of teeth in wheel
σ = Spiral angle at the cylinder at which the normal pitch is p_n and the normal pressure angle 20 deg.
ψ_n = Normal pressure angle at the cylinder at which the normal pitch is p_n. The standard normal pressure angle is 20 deg.

On the Brown and Sharpe system the blank diameter of a gear with t teeth was simply:—

$(p_n/\pi)\ (t+2)$ for a spur gear

or

$(p_n/\pi)\ (t \sec \sigma + 2)$ for a helical gear

where p_n is the normal pitch of the cutter used and σ is the spiral angle defined precisely by the relation

$$\sin \sigma = p_n/p_a$$

where p_a is the axial pitch of the gear.

There is no value of σ that is operationally better than many others, but it should preferably be selected so that p_a is less than the face-width of the gear and is a low-factored multiple $\left(\text{e.g. } \frac{12}{7}\right)$ of the axial pitch of the feed screw of the hobbing machine. The essential point is that p_a must be the same for pinion and wheel.

Gears with teeth cut to full depth in a blank of the diameter determined by the appropriate one of these formulæ are found to have unsatisfactory tooth shapes if t is smaller than $2 \cos^3 \sigma \operatorname{cosec}^2 \psi_n$, where ψ_n is the normal pressure angle, and this turns out to be a very severe restriction if σ is small.

In the following the tooth form is assumed to correspond to the British Standard basic rack tooth of which the working depth is $2p_n/\pi$ (as on the Brown and Sharpe system), the full depth is $2{\cdot}25\ p_n/\pi$ and the pressure angle is 20 deg.

Departing a little from the Brown and Sharpe system it is found that a satisfactory tooth shape is obtained with any number of teeth down to $10 \cos^2 \sigma$ if

$$\text{Blank diameter} = (p_n/\pi)[(\text{No. of teeth}) \sec \sigma + S],$$

i.e.

$$d_a = (p_n/\pi)\ (t \sec \sigma + S_p) \quad . \quad (1)$$

$$D_a = (p_n/\pi)\ (T \sec \sigma + S_w) \quad . \quad (2)$$

where S may have any value in the range defined in Fig. 1 and the suffixes p and w refer to pinion and wheel. (This range of choice provides the flexibility necessary if specified centre distances are to be observed without resorting to non-standard cutters.)

These expressions for d_a and D_a are purely empirical. They depend on no subtleties of geometrical analysis; they have been tried out and they lead to tooth forms that are neither undercut nor sharp-pointed.

Gears with teeth cut to full depth in blanks

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of these diameters have normal backlash

$$\frac{0{\cdot}65}{C}(p_n/\pi)^3(S_p+S_w-4)^3\cos^2\sigma \quad . \quad . \quad (3)$$

when meshed together at centre distance

$$C=\tfrac{1}{2}(d_a+D_a)-2p_n/\pi \quad . \quad . \quad . \quad (4)$$

which is the centre distance for engagement to the standard working depth of $2p_n/\pi$.

Settings for Hobbing Machine

Number of teeth in pinion $=t$
Number of teeth in wheel $=T$
Lead of pinion ... ... $=tp_a$
Lead of wheel ... ... $=Tp_a$
Hob setting angle (not critical) $=\sigma-$Lead angle of hob $\pm 20'$.

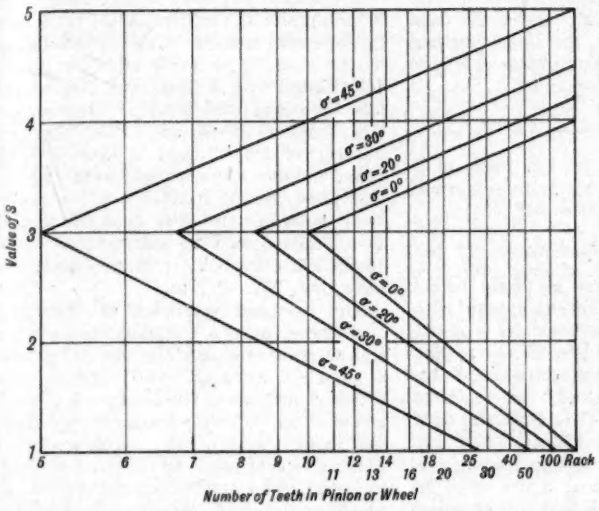


Fig. 1—Values of S for Different Numbers of Teeth

This applies to the usual case in which the hand of the spiral of the hob teeth is the same as the hand of the spiral of the teeth to be cut.

If it is desired that the backlash of the gears at centre distance C should exceed (3) by w, each gear should be cut to depth $(2{\cdot}25\ p_n/\pi)+0{\cdot}73w$.

Caliper Settings

If it is desired to check tooth thickness by gear-tooth calipers (necessary for gears generated by pinion-type cutters) instead of relying on cutting to a specified depth, appropriate values for cutting to full standard depth, giving backlash (3), are as tabulated here. For extra backlash w, the thickness-setting of the caliper is reduced by $0{\cdot}53w$ for each gear.

With these settings the calipered points are the points of contact of the tooth with the adjacent hob teeth when it is symmetrically placed in relation to them.

Caliper Settings

	Thickness	Height
Pinion	$g=(0{\cdot}321\ S_p+0{\cdot}745)\ (p_n/\pi)$	$h=(0{\cdot}442\ S_p-0{\cdot}137)\ (p_n/\pi)$
Wheel	$G=(0{\cdot}321\ S_w+0{\cdot}745)\ (p_n/\pi)$	$H=(0{\cdot}442\ S_w-0{\cdot}137)\ (p_n/\pi)$

Accuracy of Calculation

Slide-rule calculation is adequate. Exact compliance with (4) is ensured by adjusting the value of D_a, if necessary, so that

$$D_a=2C-d_a+(4p_n/\pi)$$

The errors produced in G and H by any small error in S_w cancel each other.

Comparison with Conventional Procedure

The aim in devising the foregoing method of calculating gear dimensions was to go as directly as possible to the figures required in manufacture. Only one diameter is mentioned for each gear and that is the unavoidable diameter of the blank. Permissible variation in blank diameter for a given number of teeth, cutter and axial pitch is expressed by the quantity S used directly in the formula for blank diameter. It hardly seems possible to devise any simpler way of doing what this scheme does, but suggestions are invited.

The method is the elemental one of the original Brown and Sharpe system modified to make good use of the involute system's flexibility, frequently mentioned in text books but only in ways that suggest troublesome complication and that therefore discourage its use. By its very simplicity the straightforward method may disconcert those who have long used roundabout procedure developed from the concept of the involute tooth as an unruly successor to the cycloidal form. Among the gear dimensions that are familiar in conventional procedure but superfluous in that described above are:

Addendum. Dedendum.
Addendum modification.
Pitch circle of generation.
Pitch circle of engagement.
Pressure angle of generation.
Pressure angle of engagement.
Involute function.

It is feared that there may be reluctance to part with these long-standing acquaintances, but they are not needed. In the past gear tooth forms were laboriously drawn out and transferred to gauges for checking the form of gear-cutting tools and the teeth they produced. That is not normally done nowadays, because the gear generating machine draws out the shape itself as it goes along. It is now suggested that it is equally capable of calculating all the quantities mentioned above if it needs them.

The quantities "addendum" and "dedendum" have no function but to determine blank diameter and root diameter from an imaginary "pitch diameter." The unsatisfactory character of conventional practice in this respect is clear from the fact that, unlike a cycloidal gear, an involute gear has in itself no pitch diameter. It had a "pitch diameter of generation" when its teeth were being cut; it may have had a different one if and when the teeth were being ground, and it will have a "pitch diameter of engagement" dependent on its centre distance from a mating gear, when meshed with one, but it has no intrinsic pitch diameter.

What is usually meant by "pitch diameter" is the diameter at which the normal pressure angle has the standard value. It is a landmark in the tooth, but its only practical use is the purely artificial one of being an arbitrary starting point in calculating the blank diameter by a method that has no significance with involute teeth. The difference between blank diameter and this so called pitch diameter was $2p_n/\pi$ on the Brown and Sharpe system, but as this often led to unsatisfactory tooth-shapes, departures were made from the old rule of "Addendum $=p_n/\pi$." Instead of disregarding the old procedure altogether the course was adopted of describing any departure from it as "correction" and a great deal of energy has been expended on developing rules for amounts of "correction." In general it has been thought desirable that the wheel of a pair should have equal and opposite "correction" to that of the pinion, so that the arbitrary pitch circles should be the pitch circles of engagement when the gears mesh at the designed centre distance. Fear of departure from this condition was associated with natural distaste for calculating the consequent backlash (negligible though it usually is) by the conventional method that involves use of the tiresome "involute function."

"Correction systems" have formed a delightful hunting ground for the gear technician anxious for easy publicity. Patents have actually been granted on gear teeth that were of involute form produced by standard cutters with some arbitrary amount of "correction." In such legal glamour the ordinary gear designer may be excused for having supposed that there is some special technical virtue, too obscure for him to comprehend, in following correction rules expounded with sufficient assurance. In actual fact there is none. Provided that the teeth are not nearly sharp-crested and not nearly undercut, they will work as well as any others. The attainment of minimum bending stress is dependent much more upon accuracy in manufacture and very slight departures from the true involute curve than upon practical differences between one tooth form and another. That maximum sliding velocity is unimportant may be guessed from the fact that while some experts say that it should be minimised, others have found reasons why it should be as high as possible. The unsoundness of claims for particular correction systems that they give a good balance between load capacities determined by surface stress and by bending stress becomes clear from the reflection that any desired ratio between these capacities can be obtained with any tooth-design system, by changing the pitch of the teeth on any given diameters.

The correction system in B.S.S. 436–1940 originated, so far as can be traced, with the Gleason Company in America. The procedure to be followed has to be selected from three alternatives according to the numbers of teeth concerned and there is no choice of centre distance when the pitch and the numbers of teeth are fixed. A special note says that the blank diameter calculated by the standard rule will have to be altered if the tip thickness of the tooth is to be maintained at some unspecified value but does not say whether there is any object in that. According to this system, standard cutters can be used only for gears to work at particular centre distances, as the flexibility of the involute system, proclaimed in all text books, is not used at all.

Even in B.S.S. 978, Part I (Instrument Gears), issued as late as 1952, it is insisted that for a given cutter and given numbers of teeth in spur gears, the centre distance can have only one value. An entirely false idea is thus conveyed to those readers who are not otherwise familiar with the subject, and a sense of doubt created in the minds of some who do know a little about it.

The alternatives and provisos in the B.S. gear specifications are typical of those found in other attempts to expound the so-called "correction." Small wonder that the newcomer to gear design feels unsafe in departing from the elemental Brown and Sharpe system and so we find standard cutters used badly and non-standard cutters made for jobs that could be handled with complete satisfaction on the basis of standard cutters properly used.

Remarkable trepidation seems to be felt about the fact that the working pressure angle of a pair of involute gears may not be the standard pressure angle if the Brown and Sharpe system (now stigmatised as "uncorrected") is not used. There may be a suspicion (quite unfounded) that gears

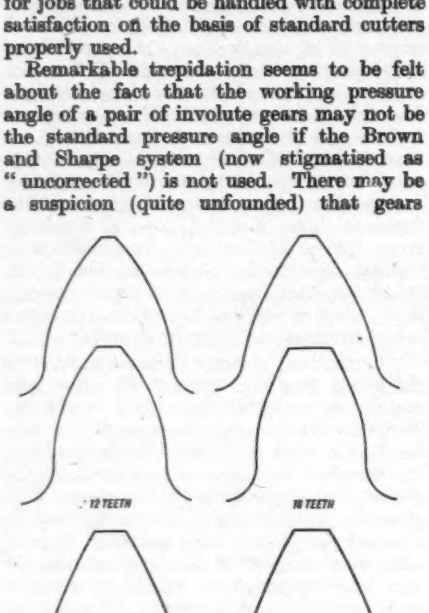


FIG. 2—EXTREMES OF SPUR GEAR TOOTH FORMS

generated by cutters of 20 deg. nominal pressure angle are not working correctly together if the pressure angle of engagement is other than 20 deg. If so that might explain reluctance to design gears in any but the old-established ways. It is here that the practical man, unhampered by imperfectly comprehended theory, has a distinct advantage. Many a time have teeth been generated in blanks of "wrong" diameters, or "wrong" numbers of teeth generated in blanks of correct diameters, but if the errors in centre distance or gear ratio can be accommodated, the gears work together quite satisfactorily. The person responsible for the error may tend to ascribe the happy result to the timely intervention of Providence, but actually it is due to the fact that the involute helicoid surfaces of all teeth cut by any hob in any blank have a common normal base pitch (that of the hob) and will therefore mesh correctly together. What is now recommended is that the flexibility that the practical man has discovered by accident should be used deliberately in the simplest possible way, ignoring the superfluous complication associated with the designer's conventional habit of thinking in terms of pitch circles and "correction." A gear generating cutter will cut any number of teeth of its own normal base pitch in any blank, and they will be usable teeth if the blank diameter lies within a particular range. All that is necessary is a simple formula (e.g. (2) above) for defining such a range. Fig. 2 shows the extremes of tooth-form corresponding to the permitted variation in S for typical numbers of teeth.

As the amount of backlash between full-depth teeth in gears of blank diameters totalling anything different from (p_n/π) $[(t+T)\sec\sigma+4]$ is a matter that troubles gear designers to the extent of frightening them away from any scheme that involves such a difference, it may be mentioned here. The highest ratio of backlash to centre distance occurs on the scheme proposed here when the total number of teeth is a minimum. For spur gears this is the case of two ten-tooth gears meshing together and from Fig. 1 the maximum value of S is 3. From (3) the normal backlash is

$$\frac{0{\cdot}65}{C}(p_n/\pi)^2(6-4)^2=\frac{2{\cdot}6}{C}(p_n/\pi)^2.$$

For $p_n=\pi$, and $t=T=10$, the value of C (from (1), (2) and (4)) is 11, and the normal backlash is

$$\frac{2{\cdot}6}{11}=0{\cdot}236.$$

If the gears are to act as pump rotors (the most likely purpose of equal gears with only ten teeth each) this backlash is about what is required for freedom from trapping of fluid. If, on the other hand, the condition of zero backlash is desired, the teeth of each gear must be cut to less than standard depth by the amount $0{\cdot}236\times0{\cdot}73=0{\cdot}172$ and this means that the bottom clearance is reduced from the standard figure of 0·25 to 0·078. That this reduction will cause no

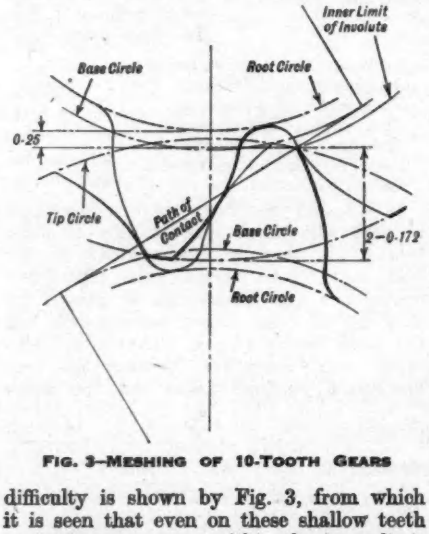


FIG. 3—MESHING OF 10-TOOTH GEARS

difficulty is shown by Fig. 3, from which it is seen that even on these shallow teeth contact never occurs within the inner limit of the involute part of the tooth-profile.

The essence of the matter is that the backlash with full depth is relatively large only where the total number of teeth in wheel and pinion is small; even in that circumstance it is safe to eliminate the backlash by cutting shallow teeth, because even then the contact does not extend into the normal clearance space, although the tip of the mating tooth does so.

SELECTION OF AXIAL PITCH

Helical gears cut by the rack-generating process on machines like the Sunderland have axial pitch equal to the transverse pitch of the cutter multiplied by the cotangent of the angle between the cutter box guides and the axis of the work. In other words, the axial pitch of the gear is the pitch, measured parallel to the axis of the gear, of the rack teeth represented by the cutter.

Helical gears cut on Fellows or Sykes machines have axial pitch equal to the lead of the helical cutter guide divided by the number of teeth in the cutter.

Helical gears cut on hobbing machines may be given any axial pitch within the scope of the machine. As the setting up of a hobbing machine to cut helical gears involves the selection of charge wheels to give a velocity ratio proportional to the axial pitch of the gear to be cut, it is obvious (when pointed out) that the axial pitch should preferably be chosen so as to make the selection of charge wheels easy, but this is rarely done.

A common practice, arising out of failure to comprehend that the axial pitch is the fundamental measure of the helical character of the gear, is to work on some arbitrary spiral angle, say 30 deg., and then to calculate the axial pitch from $p_a=p_n\operatorname{cosec}\sigma$. If this works out to an exactly factorable number of inches (and it does if p_n is a round number of inches and $\sigma=30$ deg.), well and good, but if it does not the result is such a frequently seen type of absurdity as a lead specified on a drawing to be (say) 76·38317in, whereas it might equally well have been 76in or 77in.

The essential condition is that mating gears must have a common axial pitch and this shows at once that the rational procedure is to select an axial pitch that is a low-factored multiple of the axial pitch of the feed screw of the hobbing machine, regardless of the exact value of the spiral angle. The nominal spiral angle is then determined by slide-rule calculation from the normal pitch and the axial pitch. It is used in determining the range of permissible blank diameter for a given number of teeth and in determining the setting angle for the hob. This latter is not critical to anything less than about 20 minutes of angle. The lead of the gear, and the spiral angle at any radius, are determined by the set-up of the "spiralling mechanism" of the hobbing machine and are not influenced in any way by the angular position of the hob. The only limitations on the setting angle are imposed by the necessity of having cutting relief angle on both flanks of each hob tooth. Within this tolerance, the setting angle has no measurable effect on the form of the teeth of the work and none at all on their lead.

The proposals outlined here involve no conflict with any existing procedure. The latter gives, after some needless complication, solutions of limited utility, whereas the recommended method is to calculate manufacturing dimensions directly in a way that avoids any need for non-standard cutters whatever centre distance is required for the mating gears. It is thus in one way a reversion to very old practice, commonly used with the Brown and Sharpe system of gearing, but obscured because the idea of "correction" was applied to the imaginary addendum instead of specifying a permissible range for the tangible blank diameter.

DESIGN PROCEDURE

From (1), (2) and (4)

$$2C=(p_n/\pi)[(t+T)\sec\sigma+S_p+S_w-4],$$

whence

$$p_n=\frac{2\pi C}{(t+T)\sec\sigma+S_p+S_w-4} \quad . \quad . \quad (5)$$

and

$$S_p+S_w=(2C\pi/p_n)+4-(t+T)\sec\sigma \quad . \quad (6)$$

Equation (5) makes it possible to determine directly the permissible range of normal pitch for given centre distance, numbers

of teeth and spiral angle by inserting in it, first, the maximum permissible values of S_p and S_w, and, secondly, their minimum permissible values.

When a normal pitch has been selected from the available range, equation (6) specifies the sum of S_p and S_w. Within this limitation and that of Fig. 1, any combination of S_p and S_w may be used, but an arbitrary procedure is suggested for general guidance.

(1) Make $S_p=S_w=\frac{1}{2}(S_p+S_w)$ if this value lies within the range permitted for S_p by Fig. 1.

(2) If $\frac{1}{2}(S_p+S_w)$ exceeds the maximum permitted for S_p by Fig. 1, give S_p the maximum permitted value.

(3) If $\frac{1}{2}(S_p+S_w)$ is less than the minimum permitted for S_p by Fig. 1, give S_w (for the wheel) the minimum value permitted by Fig. 1.

Special Case.—If the wheel normally drives the pinion, S_p should preferably have the minimum permitted value, but must not be greater than S_w.

General.—If (S_p+S_w) lies outside the limits permitted by Fig. 1 for the particular values of t and T, another combination of numbers of teeth may be tried or, in the case of helical gears, the spiral angle may be changed.

Numerical Example.—

Let $t=18$
$T=41$
$\sigma=30$ deg.
$C=10$in.

The value of p_n is determined from (5), first, for the maximum permissible values of S_p and S_w and, secondly, for their minimum permissible values. From Fig. 1 the former are $S_p=3\cdot95$ and $S_w=4\cdot25$, and the latter are $S_p=1\cdot6$ and $S_w=1\cdot1$.

$$\text{Min. } p_n=\frac{2\times10}{(18+41)\sec 30\text{ deg.}+4\cdot2}=0\cdot870$$

$$\text{Max. } p_n=\frac{2\times10}{(18+41)\sec 30\text{ deg.}-1\cdot3}=0\cdot94.$$

The standard normal pitches 0·875, 0·8976 (3½ D.P.) and 0·9375 are within this range. Adopting the middle one, the corresponding axial pitch for $\sigma=30$ deg. is 0·8976 cosec 30 deg.=1·7952, which is an unnecessarily inconvenient number. Substituting $p_a=1\cdot8$ to facilitate change-gear calculations,

$$\sin\sigma=\frac{0\cdot8976}{1\cdot8}=0\cdot499$$

whence

$$\sigma=29\cdot93\text{ deg.}$$

and for this purpose this value is indistinguishable from 30 deg.

Using this in (6),

$$S_p+S_w=(2\times10\times3\cdot5)+4-(18+41)\sec 30\text{ deg.}=5\cdot8.$$

Now $\frac{1}{2}(S_p+S_w)=2\cdot9$, and this is within the permitted range for S_p. This value is therefore adopted for both S_p and S_w. Hence from (1) and (2),

$$d_a=\frac{1}{3\cdot5}(18\sec 30\text{ deg.}+2\cdot9)=6\cdot77$$

$$D_a=\frac{1}{3\cdot5}(41\sec 30\text{ deg.}+2\cdot9)=14\cdot36.$$

From (4)

$$C=\frac{1}{2}(6\cdot77+14\cdot36)-\frac{2}{3\cdot5}=9\cdot994.$$

To correct this small discrepancy of 0·006, take

$$D_a=2C+\frac{4p_n}{\pi}-d_a=21\cdot143-6\cdot77=14\cdot373.$$

The essential manufacturing particulars of the gears are, therefore :—

1. Use hob of British Standard tooth form 3½ D.P. normal.
2. Axial pitch of pinion and wheel=1·8in.
3. Blank diameter of pinion=6·770.
4. Blank diameter of wheel=14·373.
5. Spiral angle of pinion and wheel=30 deg.

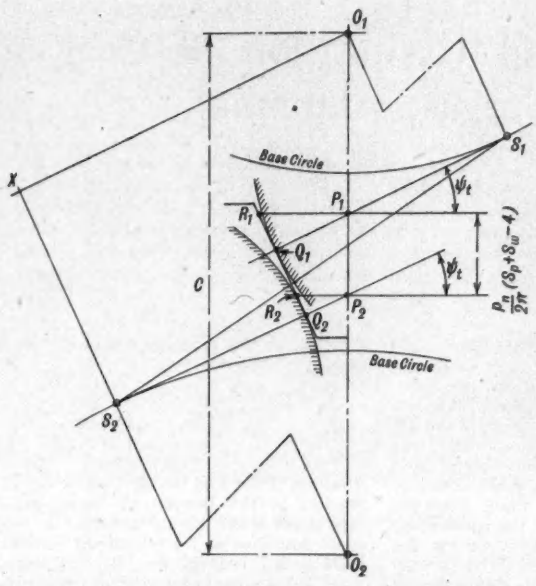


FIG. 4—BACKLASH BETWEEN FULL DEPTH TEETH

6. Standard caliper settings :
   Thickness $g=G$
   $=(0\cdot321\times2\cdot9+0\cdot745)/3\cdot5=0\cdot479.$
   Height $h=H$
   $=(0\cdot442\times2\cdot9-0\cdot137)/3\cdot5=0\cdot327.$
   (Because $S_p=S_w$ in this case, the caliper settings are the same for both pinion and wheel.)
7. Backlash with standard caliper settings (from (3)),

$$\frac{0\cdot65}{10}(1/3\cdot5)^2[5\cdot8-4]^2\cos^2 30\text{ deg.}=0\cdot013$$

To reduce this to zero, if desired, each thickness setting must be

$$0\cdot479+0\cdot53\times0\cdot013=0\cdot486.$$

All these calculations are adequately effected by slide-rule.

NOTE.—In the case of helical gears, any specified centre distance may be accommodated by adjustment of spiral angle with fixed values of S_p and S_w. In the numerical example given above, however, this possibility was not used, but the specified spiral angle was maintained (apart from a small adjustment to obtain a rational axial pitch) to demonstrate how the permitted variation in S may be used to adapt the design to a specified centre distance.

DETAILS NOT REQUIRED IN DESIGN

Although the usual text-book analysis of involute gear geometry is capable of answering any question that the inquiring gear technician may ask about the basis of the procedure described above, it may be useful to insert some guidance for those who are tempted in that direction.

Pitch diameter of generation

$$=\frac{\text{No. of teeth}}{\pi}\cdot\frac{p_a p_n}{\sqrt{(p_a^2-p_n^2)}}.$$

Base diameter

$$=\frac{\text{No. of teeth}}{\pi}\cdot\frac{p_a p_n\cos\psi_n}{\sqrt{(p_a^2-p_n^2\cos^2\psi_n)}}.$$

Pitch diameters of engagement

$$\frac{2Ct}{t+T}\text{ and }\frac{2CT}{t+T}.$$

Transverse pressure angle (ψ_{te}) of engagement is defined by

$$\cos\psi_{te}=\frac{\text{Sum of base diameters}}{2C}.$$

The derivation of (3) is based on the fact that over a short arc the involute is a close approximation to a circular arc, and is illustrated by Fig. 4, which represents a transverse section of a pair of helical gears. The pitch circles of generation of pinion and wheel intersect the line of centres at P_1 and P_2, separated by a distance

$$\frac{p_n}{2\pi}(S_p+S_w-4).$$

Teeth symmetrically disposed about O_1O_2 touch the transverse section of the generating rack tooth flank (transverse pressure angle ψ_t) at Q_1 and Q_2; the feet of the perpendiculars from P_1 and P_2 and the centres of curvature of the involutes at these points are S_1 and S_2 respectively, the points of tangency of the perpendiculars to the base circles. The radii of curvature are S_1Q_1 and S_2Q_2. By dropping a perpendicular O_1X from O_1 to the extended radius O_2S_2 it can be seen that $S_1Q_1+S_2Q_2=O_1X=C\sin\psi_t$.

The two tooth profiles touch the rack profile at points separated by the distance Q_1Q_2, which is $P_1P_2\cos\psi_t$.

The normal clearance between the tooth profiles in this transverse section is the difference between S_1S_2 and the sum of the radii of the circular arcs.

Now

$$S_1S_2=\sqrt{[(S_1Q_1+S_2Q_2)^2+Q_1Q_2^2]}$$

and so

$$S_1S_2-(S_1Q_1+S_2Q_2),$$

which is a small difference, is equal to

$$(S_1Q_1+S_2Q_2)\sqrt{\left[1+\left(\frac{Q_1Q_2}{S_1Q_1+S_2Q_2}\right)^2\right]}-(S_1Q_1+S_2Q_2)$$

$$\doteq\frac{1}{2}\frac{(P_1P_2\cos\psi_t)^2}{C\sin\psi_t}$$

$$=\frac{1}{8C}(p_n/\pi)^2\frac{(S_p+S_w-4)^2}{\sin\psi_n\sec\sigma_o}\left(\cos^2\psi_n\frac{\cos^2\sigma}{\cos^2\sigma_o}\right)$$

where σ_o is the base spiral angle.

The clearance between the helical tooth profiles measured normal to them is determined by multiplying this quantity by $\cos\sigma_o$ and the total normal backlash is twice this.

Hence :

Normal backlash

$$=\frac{1}{4C}(p_n/\pi)^2(S_p+S_w-4)^2\frac{\cos^2\psi_n}{\sin\psi_n}\cos^2\sigma.$$

For $\psi_n=20$ deg., this becomes

Normal backlash

$$=\frac{0\cdot65}{C}(p_n/\pi)^2(S_p+S_w-4)^2\cos^2\sigma.$$

CONCLUSION

Simplicity is a sound ideal in all engineering design. It is particularly important in a standard specification because that is the natural resort of an engineer who seeks guidance in a specialised subject. The more specialised the terminology and the more complicated the procedure laid down in a standard specification, the less likely is it to be applied. Even now great use is made of old tables of "gear tooth parts" on the Brown and Sharpe system, because the formulæ given are extremely simple. The objections to them are that they do not indicate that non-standard cutters need never be used and that compliance with them does not make the best use of standard cutters. The aim of the system described in this article is to offer the utmost simplicity consistent with full and efficient use of standard tools.

Underground Gasification of Coal at Gorgas, Alabama

During the autumn and winter of 1946–47 *an experiment in the underground gasification of coal was conducted by the U.S. Bureau of Mines and the Alabama Power Company. A second experiment was started in March,* 1949, *and concluded* 22½ *months later. This article describes the necessary constructional work, gives particulars of the operational results, and discusses the conclusions that can be drawn. For part of the experiment gas turbine driven superchargers were employed to supply the necessary air.*

IT may be recalled that the U.S. Bureau of Mines and the Alabama Power Company jointly conducted a first experiment in underground gasification of coal at Gorgas, Alabama, during the autumn and winter of 1946–47. This preliminary experiment showed that it was not difficult to maintain combustion of coal underground, and that coal in place could be completely gasified. It was noted that the high temperature developed by the gasification of coal in place brought about changes in the overlying strata which appeared to be favourable to the process. The high temperatures caused the roof rock to become plastic, to expand, and to settle down on the mine floor directly behind the reacting coke face. These results were considered promising enough to warrant further investigation of the process. It was believed that if this action could be controlled properly with roofs of similar composition it would tend to force the gas-making fluids underground against the coal faces. Plans for the second experiment were based in part on this favourable roof action, and the successful operation of the planned initial straight-line passages depended on this fact.

Gorgas was chosen as the site for the second experiment for the following reasons:—A tract of coal land of sufficient size was available, isolated from the main body of coal; the roof rock was similar in composition to that encountered in the first experiment; and the overlying strata were thick enough to eliminate some of the operating difficulties that had been encountered. In addition, power, water and machine shop facilities as well as an adequate supply of labour were available in this area. The coal bed selected dips approximately 1 deg. 55 min. in the direction a little east of south. In this area the coal ranges in thickness from 40in to 44in. Vertical face cleats in the coal are closely spaced, averaging twenty cleats to the foot and running S. 50 deg. W. Starting at the top, the coal bed can be described as follows:—

Inches		
7	... ...	Bright coal
2	... ...	Bone
7	... ...	Coal
½	... ...	Bone or fusain
24	... ...	Coal with streaks of bone or fusain

Analysis of the coal by the Central Experiment Station of the Bureau of Mines led to its classification as "highly volatile 'A' bituminous," described as "good coking" quality. In this second underground gasification experiment it was planned to utilise the principles of the "stream method," wherein the gas-making fluids flow past a coal face and make contact with it. The exposed face is the full thickness of the coal bed, and, as the carbonaceous material is gasified the face recedes. It was decided to use a straight-line passage in the coal bed with inlet and outlet connections to gasify the coal exposed, and to advance the combustion of an area by constructing new inlets or outlets off the line of the original passage as needed. Thus, an area would be gasified in roughly triangular increments. This system was dependent on the roof action in an adjacent burned-out increment, so that the blast medium would always be forced against reacting coal faces. The roof action in the first experiment was thought adequate to make this plan applicable. It was decided to use air as a gasification medium, as it was believed that the information obtained would be fundamental, and, by using air, the cost of the gas-making fluids would be reduced materially, as compared to using oxygen.

The primary objectives of this second experiment at Gorgas were to extract the energy contained in unmined coal and to obtain fundamental knowledge relating to the underground gasification of coal by:—

(1) Determining the quantity of coal which can be gasified from a given initial combustion zone and the shape and extent of the burned-out area formed by this gasification;

(2) Determining the quality and quantity of the air-blow product gas generated at the conditions of the experiment;

(3) Determining the operational characteristics of the system as designed and constructed, including such fundamental factors as the optimum length of passage, the optimum rate of fluid flow and the pressure drop encountered;

(4) Obtaining information regarding the action of heat on the overlying strata; and

(5) Obtaining technical and economic information with regard to the choice of plant sites, installations and operating procedures, including the installation and testing of air inlets and gas outlets, both as vertical bore-holes to the coal bed and as stoppings in the coal bed near the outcrop.

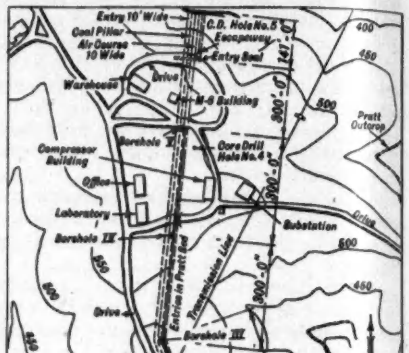


FIG. 3—PLAN OF PROJECT

CONSTRUCTION

The second experiment in the underground gasification of coal at Gorgas was operated continuously for 22½ months. As shown in Fig. 3,

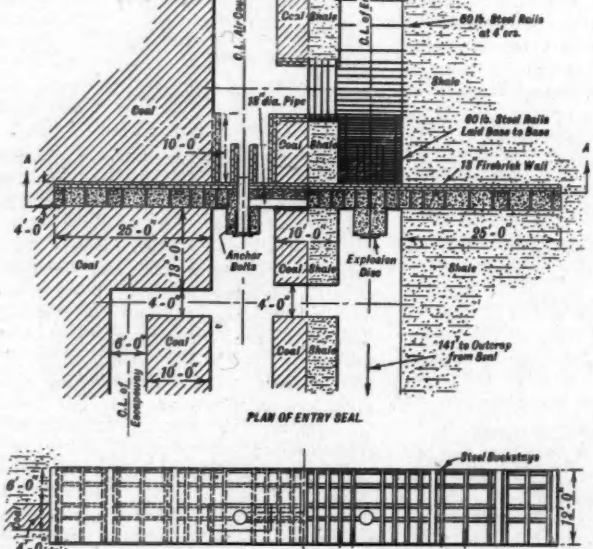


FIG. 1—ENTRY SEAL

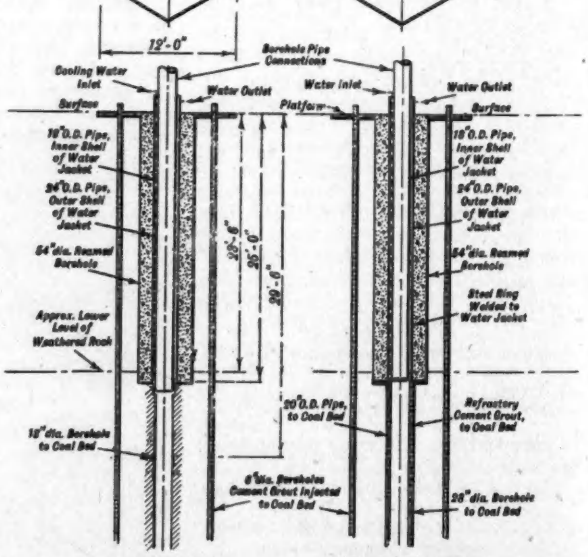

8'-0"
12'-0"
Borehole Pipe Connections
Cooling Water Inlet
Water Outlet
Water Inlet
Water Outlet
Surface
Platform
Surface
18" O.D. Pipe, Inner Shell of Water Jacket
24" O.D. Pipe, Outer Shell of Water Jacket
54" dia. Reamed Borehole
Steel Ring Welded to Water Jacket
Approx. Lower Level of Weathered Rock
20" O.D. Pipe to Coal Bed
Refractory Cement Grout, to Coal Bed
18" dia. Borehole to Coal Bed
6" dia. Borehole Cement Grout Injected to Coal Bed
30" dia. Borehole to Coal Bed
UNLINED BOREHOLES. BOREHOLES. I & V
REFRACTORY LINED BOREHOLES. BOREHOLES. II, III & IV

FIG. 2—BOREHOLE INSTALLATION

the initial development consisted of 1100ft of double entry between bore-hole II and the entry seal driven horizontally in the coal bed and a single entry 300ft long connecting bore-hole II with bore-hole I. These entries provided a passage for the gas-making fluids along the coal faces. The entry seal, which is shown in Fig. 1, consisted of a three-course wall of fire-brick backed with steel buckstays. The top and inby sides of this wall were pressure grouted to the roof and surrounding stratum with neat cement admitted through the four 6in bore-holes shown. After grouting the wall, the inby and outby exposed surfaces were grouted with a refractory cement applied with a cement gun. Later, the air space along the outby face of the seal was filled with concrete made from cement, rock dust and sand. The 24in diameter outlet pipes were set in concrete, as shown, and the explosion discs were set in flanges anchored to the concrete surrounding the outlet pipes. A fan and fan house were erected and connected to the escapeway in such a way that at all times men could travel underground to the entry seal without danger of interruption of air supply. The portals of the air course and entry were fitted with doors and regulators so that the air flow could be controlled as desired when work at the entry seal was necessary. The roof of the entry from the portal to bore-hole I was supported by steel rail set in hitches in the top coal and secured by wedges of stone or brick. The steel rails were approximately 13ft long and were placed on 2ft centres.

Five large-diameter bore-holes situated on 300ft centres were drilled from the surface to the entries, and subsequently two additional large-diameter bore-holes were drilled near the perimeter of the reacting zone in order to introduce air at the horizon of the coal bed and to remove gas and products of combustion. Before drilling the large bore-holes I to V, inclusive, the area through which each hole was to be drilled was pressure grouted with cement. The arrangement of the pressure grout holes is shown in Fig. 2. Grout was applied in the unlined holes from a depth of 30ft below the surface to the coal bed. Each of the bore-holes was fitted with a surface seal. In order to accommodate the seal, each bore-hole had been reamed to 54in diameter for varying depths. After placing the water jacket the annulus was filled with concrete and the surface pad was poured. The purpose of the water jacket at each bore-hole was to maintain a tight seal between the concrete surface plug and the bore-hole casing and was not intended as a means of cooling the effluent gas.

On the surface a 20in diameter air blast manifold was installed to connect the large bore-holes with the compressor units. The connections to the bore-holes were equipped with valves, so that each could be used either as an air inlet or a gas outlet. Each of the bore-holes was fitted with an internal water spray, thermo-couples and sampling connections. The thermo-couples normally were situated at the gas sampling point and at a depth of 40ft below ground level. Recording flow meters as well as temperature and pressure measuring devices were installed in the air manifold. The primary air source for the project was a reciprocating compressor powered by an 800 h.p. synchronous motor having a rated capacity of 7200 cubic feet per minute of free air at a discharge pressure of 30 lb per square inch gauge (Fig. 4). Auxiliary air compression equipment consisted of two rotary, positive pressure blowers. One of these was powered by a 100 h.p. motor and had a rated capacity of 1600 cubic feet per minute of free air at 10 lb per square inch gauge. The other unit had a rated capacity of approximately 7000 cubic feet per minute of free air with a discharge pressure of 2 lb per square inch gauge and was powered by a 75 h.p. motor.

Two mobile gas sampling units were built and connected to the outlet stacks as desired. These units included a primary condenser, a coke filter tower, a secondary tubular condenser, a gas pump, an after condenser, and flow measuring equipment, as shown in Fig. 5. The gas leaving the units was piped to the laboratory, where iron oxide boxes, a 100 cubic foot gas-holder, and a pressure regulator were installed.

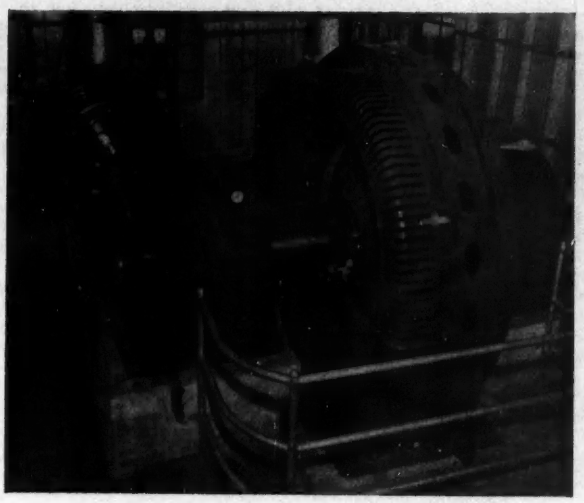


FIG. 4—RECIPROCATING AIR COMPRESSOR

From the iron oxide boxes the gas sample was piped to a recording calorimeter and to a recording gravitometer in the laboratory building.

It was decided to install two turbo-superchargers similar to those used in aircraft engines, to obtain some information on the possibilities of operating gas turbines in connection with underground gasification. At bore-hole III the gas turbine installation shown in Fig. 6 was constructed. It consisted of five cyclone knock-out chambers acting in parallel for the removal of dust and clinker from the effluent gas. The discharge from the knockout chambers was connected to the intakes of two gas turbines connected in parallel. In each turbo-compressor the turbine and the air compressor were mounted on the same shaft. Two stages of compression were obtained as air was admitted to one compressor unit, and this discharged into the intake of the second. The discharge from the second compressor was added to the air stream entering the underground system or discharged to the atmosphere. All units comprising the gas turbine installation were mounted on concrete foundations. The knockout chambers and the hot gas-handling lines were insulated with 2in of magnesia asbestos lagging. Steel barricades were erected around the turbo-compressor units, and an adequate oil cooling and storage system was installed. The gas discharge from the gas turbines was vented to the atmosphere through a 20in diameter stack.

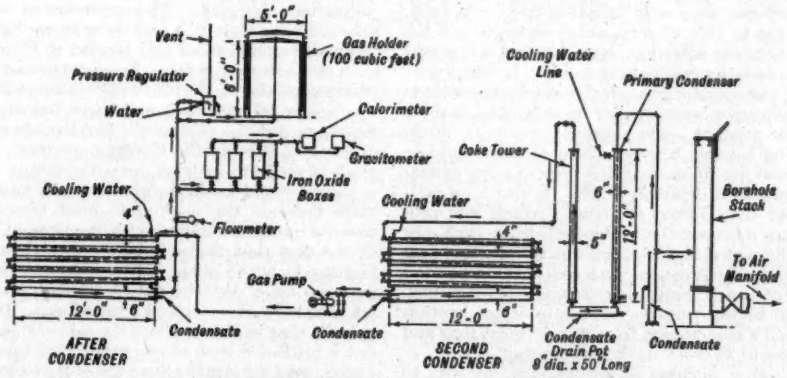


FIG. 5—GAS COOLING, CLEANING AND SAMPLING EQUIPMENT

OPERATION

Operation of the project was divided into several periods. Various problems developed and certain operational changes were made. In each instance the changes were planned either to correct difficulties encountered or to obtain information regarding the effect of certain variables on the process. To fire the project each rib of the 300ft single entry between bore-holes I and II was undercut to a depth of 15in and the loose coal obtained was piled against the ribs. Approximately 15 tons of coal was placed around the base of bore-hole I and along the ribs of the entry. Several cords of pine-wood was stacked on top of the coal and a number of thermite fire bombs was placed in the pile of fuel. One hundred gallons of fuel oil was poured down bore-hole I. The 1600 cubic foot per minute compressor was started and at 3 p.m. on March 18, 1949, a thermite bomb was dropped down bore-hole I, causing operation of the project to begin.

On February 7, 1951, operation of the project was discontinued, and, in order to extinguish the fire and cool the underground residue, flooding the system with water was started. Water was pumped underground at the rate of about 60 gallons per minute, and the steam liberated was discharged at the several bore-holes as desired. The water pumped underground vaporised and was discharged as steam, dissociated and left the system as gas or remained as liquid in the passages underground. Steam or water saturated dried strata adjacent to the combustion zone. The steam which formed, provided its discharge was throttled, asserted a positive pressure underground and blanketed the system effectively and precluded the possibility of air reaching hot carbon.

During the operation 10,485 short tons of moisture and ash-free coal was consumed, underlying an area of 83,690 square feet adjacent to the original entry. Up to the time the project was discontinued no difficulty had been experienced in maintaining combustion, and no limit as to the ultimate quantity of coal which could be gasified from a given opening had been determined.

It was part of the original plan to extend the gasification to cover a large area of coal bed by providing new inlets and outlets by drilling bore-holes off the line of the original entry and tangent to the perimeter of the burned-out area. This was done in the course of the experiment, and it was found that the gasified area could be extended thus. A bore-hole drilled 75ft east of bore-hole II made contact with the reacting face and was utilised to advance the face further. It appears that there is no definite limit to the area of coal bed that may be exploited in this manner. A second objective of the experiment was to determine the quality and quantity of the product gases produced when using air for combustion. Gaseous products having a heating value of 90 to 150 B.Th.U. per cubic foot were obtained at times during the operation of

the project. During the operation between bore-hole II and a new bore-hole VI, which was drilled at the perimeter of the burned-out area, a combustible gas with a heating value of 90 B.Th.U. per cubic foot was produced at a rate of 9,400,000 cubic feet per day. In this instance the effective period of operation was only eight hours, because the walls of the outlet fused and the bore-hole was destroyed. Subsequently, during operation of the section between bore-hole III and another new bore-hole, VII, a production of 6,700,000 cubic feet per day of gas with a heating value of 72 B.Th.U. per cubic foot was attained. In each of the above instances the new bore-hole was drilled at the perimeter of the burned-out area, which resulted in a product of improved quality as well as the extension of the gasification over a larger area. It was found that maintaining efficient contact between the gas-making fluids and the carbonaceous faces was a prerequisite for recovering maximum energy from the coal either in the form of a combustible gas or as sensible and latent heat in the gaseous products. A large proportion of the work at the project was therefore directed toward obtaining efficient contact.

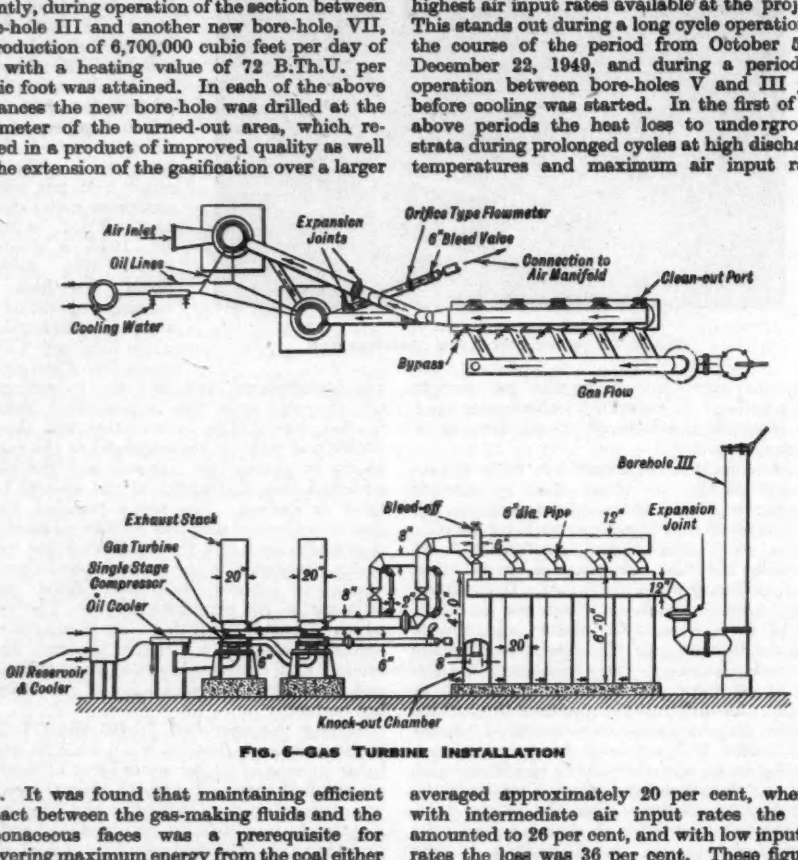


FIG. 6—GAS TURBINE INSTALLATION

Partial solutions were achieved, and various procedures were indicated for further attack. The use of 10ft wide openings underground did not promote efficient contact between the coal faces and the gas-making fluids. It was found that the dimensions of the original openings should have been smaller in order to obtain a better product. Some success was achieved in forcing contact between the coal faces and the gas-making fluids by filling void spaces underground with liquefied solids. It has been estimated that during periods in which this procedure was used the contact efficiency probably was increased fourfold, and the utilisation of new inlets and outlets near fresh coal faces and off the line of the original underground openings provided better contact. The rate of combustion of coal was increased from 9 to 18 short tons and thence to 30 to 45 short tons per day.

Another purpose of the experiment was to determine the optimum rate of air input for a given system. Consideration of the results obtained and a study of the moisture inflow to the system indicates that the fluid flow must be maintained at such a quantity that the heat losses from the evaporation and dissociation of moisture do not become excessive. No criterion as to the permissible limit of heat loss due to moisture was established, but it is believed that the volume of fluid flow through the system must be maintained large enough so that the heat loss from this cause does not exceed 5 to 15 per cent of the heat of combustion of the coal consumed. If the fluid flow was reduced in quantity the heat loss from this source tended to increase beyond these figures, and an adequate temperature level could not be maintained. During periods of operation when the rate of fluid flow was relatively low the percentage moisture content of the effluent gases was high and heat losses from the system were excessive. Under such conditions the operating characteristics of the system deteriorated rapidly. Heat balances obtained during the operation consistently show maximum energy recovery in the effluent gases during prolonged periods of operation in one direction at the highest air input rates available at the project. This stands out during a long cycle operation in the course of the period from October 5 to December 22, 1949, and during a period of operation between bore-holes V and III just before cooling was started. In the first of the above periods the heat loss to underground strata during prolonged cycles at high discharge temperatures and maximum air input rates averaged approximately 20 per cent, whereas with intermediate air input rates the loss amounted to 26 per cent, and with low input air rates the loss was 36 per cent. These figures indicate that high rates of coal consumption and high rates of fluid flow are desirable in underground gasification.

The action of the immediate roof in regions outside the original underground passages where the coal was burned out has not yet been completely assessed. The information available indicates that this roof came down behind the reacting coal faces and tended to force the fluid flow toward the face. It was expected that bloating of the roof rock would completely fill the space where coal had been consumed. Although definite evidence is lacking, there are indications that partial bloating occurred. The gradual increase in back pressure during each of the operating periods shows that the passageways between the inlet and outlet bore-holes became more constricted with the time in spite of the fact that the volume of coal consumed increased with time; however, in every instance holes drilled into the burned-out area admitted air or water and emitted gas. It was evident that in places where the coal was burned out a restricted flow of gas existed. Prolonged exposure of the strata above the coal bed to heat caused cracking and added to the permeability of the burned-out area. In all cases the growth of the burned-out area resulted in a deterioration in the operating characteristics. The measured rate of advance in the area between bore-holes I and II ranged between 1·25in and 2in per day. It was likely that this rate was exceeded in the area between bore-holes VII and III; however, the rates here were not measured. Theoretically, the total heat lost to the strata should decrease with increasing rate of advance of the reacting face. The source of heat is the reaction, and, with a higher rate of advance, less total time would be available for heat to penetrate into the rock above and below the coal bed.

The operation at Gorgas indicated that the optimum conditions for underground gasification employing the stream method required high rates of reaction and rapid movement of the coal faces underground in order to minimise heat losses from the system. In addition, the operation consistently indicated that when fresh coal faces were exposed near the inlet or outlets to the system the best contact efficiency and the best energy recovery, either in the form of a combustible gas or as heat, were obtained.

Studies were made of leakage from the underground system during various periods of operation. These indicate that leakage increased gradually with time up to approximately 50 per cent of the total fluid input and remained fairly constant at this figure. There were indications that the increase in leakage was influenced by subsidence of the strata overlying the burned-out region causing cracks through which the gas escaped. Several initial leaks were found in early operations, but these accounted for only a small proportion of the leakage that eventually occurred. The figure of 50 per cent was exceeded when higher pressures were placed upon the underground system by closing off or choking the gas outlets. It was possible that long exposure to heat and subsequent drying of strata increased leakage. Furthermore, the applied air pressure could force moisture back into the capillaries of the strata and thus reduce the sealing effect of water.

An objective of the experiment was to determine the optimum length of underground passage which could be used. It was found that quadrupling the surface area of the coal faces initially available increased the rate of consumption of coal by a factor of approximately 2·5. This was based upon a comparison of the operation between bore-holes I and II before any "fluidised" sand was injected underground, and the operation between bore-holes III and V.

Various designs of equipment and systems of construction were tested during the experiment. It was found that the installation of a water jacket between the bore-hole casing and the concrete surface seal was very effective for handling hot gases, and caused exit bore-holes to be operable for long periods. Refractory lined bore-holes handling hot gases did not prove superior to unlined bore-holes, and the extra cost of using refractories in future installations does not appear justified. The use of pressure grouting techniques in areas surrounding an outlet hole as a means of decreasing the porosity of the stratum which was traversed by the opening appears to be advantageous. This technique can be used also in decreasing leakage over limited areas, as the grout will fill horizontal and vertical cracks intercepted by the hole. The construction of the entry seal was adequate for the service required. Leakage from this seal was not excessive, but a more satisfactory method of construction calls for sinking the seal to a greater depth in the bottom rock and improving the application of pressure grouting techniques. It is believed that the use of supporting brickwork around the base of the bore-holes serving as inlets and outlets might help in prolonging the life of the openings in question; however, there was little difference between the service obtained at bore-hole VII, where it was not possible to use this construction, and the service of the brick-supported bore-holes I to V.

OPERATION OF THE GAS TURBINES

During operations concentrated in the region between bore-holes VII and III it was decided to set up one of the two small gas turbines at bore-hole III. The primary purpose of this installation was to increase the air input at bore-hole VII and to obtain operating characteristics of the system, using flow rates exceeding the maximum previously employed. It was also desired to learn something of the operating characteristics of the system at a higher average pressure, and a further objective was to determine whether the effluent gases could be used in a gas turbine without requiring excessive cleaning of the gases to prevent solids accumulation and corrosion and erosion of the turbine blades and auxiliary equipment.

A single turbo-supercharger unit was installed at bore-hole III and tested during several cycles at a temperature range of 400 deg. to 600 deg. Fah. It was found that the maximum

pressure obtainable at bore-hole III was 10 lb per square inch gauge, and under these temperature and pressure conditions one turbo-supercharger unit would not operate at an adequate efficiency level to pump air into the manifold against the discharge pressure of the reciprocating compressor. Furthermore, the low temperature of the effluent gases favoured the deposition of tarry material on the turbine blades, and after a few hours' operation this deposit caused a serious drop in the turbine efficiency. With an input pressure of 10 lb per square inch gauge it was found that the single turbine unit would operate at a speed of 14,000 to 16,000 r.p.m.

Because these tests showed that a single turbine unit was inadequate to pump air at the required pressure a second turbine was installed. The two turbo-supercharger units were connected as shown in Fig. 6. The turbine ends of each machine were connected in parallel and the compressor ends were connected in series. This installation permitted a greater mass flow through the turbines and gave two stages of air compression. Preliminary tests on the units connected in this manner indicated that the compressors could be used to increase the air input to the mine. During the testing of the turbo-superchargers the gasification project was operated with an average pressure of 17·5 lb per square inch gauge on the input air and 9·4 lb per square inch gauge on the effluent gas. The average pressure on the underground system was thus 13·5 lb per square inch gauge. Throughout the test the oxygen content of the effluent gas was negligible, the rate of coal consumption was high, and the heating value of the gases discharged from the turbines increased steadily with time. At first the flame due to the burning gases was visible only around the perimeter of the turbines, where the gases entered the discharge stacks; but subsequently the gas discharged from the two 20in stacks was burning, and the height of the flame cone increased with time. The increased total pressure and the resultant increase in partial pressure of the oxygen underground resulted in a general improvement in gas quality and in operating characteristics.

Results of the turbo-supercharger operation are summarised in the above table. Under test conditions the speed of each unit ranged from 14,000 to 16,000 r.p.m. The cyclone knock-out chambers installed ahead of the turbines removed a small quantity of fine dust, and occasionally quantities of dust went through the turbines. Examination of the turbine blades following this test and including some thirty hours of prior operation did not reveal any serious damage or build-up on the blades. This was qualitative only as the effect of the dust on the blading would have to be determined over long operating periods. Throughout the test water was sprayed into the effluent gases at the base of bore-hole III to prevent the temperature from rising above 1400 deg. Fah. The temperature level was held at the desired value, but at the end of the eighth period the refractory lining slumped and blocked bore-hole III at two points. This slumping took place at points 42ft and 52ft below the surface of the ground. At each elevation the blocked portion was not extensive, for it was later possible to reopen the bore-hole by punching a hole through the obstructed regions. A length of steel rail having one end forged into a bit was allowed to fall freely through a distance of 15ft. A few blows sufficed to punch through each obstruction. Further tests with the turbo-supercharger units were not made.

The turbo-supercharger test showed qualitatively that it was possible to use the effluent gas produced by underground gasification. Although the operating efficiency of the turbo-supercharger units was not high, the test showed that if the outlet pressure was increased to a more satisfactory level and more efficient units were installed the recoverable energy would be increased at least three or four times. Furthermore, the heating value of the gas was wasted in this test and could be utilised in a more efficient installation. By making these changes it is considered possible to supply an underground gasification system with air and make a considerable portion of the energy of the coal available as a product.

While the underground gasification of coal is still in the experimental stage, several results which appear to be favourable from an economic point of view have now been obtained. The quantity of coal which can be gasified from an initial opening in the coal bed is presumably limited, but to date no definite limit has been reached. More than 5000 short tons of coal from a bed 42in thick have been gasified from the ribs of an initial 300ft entry in the coal bed. It has been possible to enlarge the area of coal consumed by constructing new inlets and outlets near the combustion faces. The energy of the coal can be brought out of the ground as sensible and latent heat of the effluent gases, and qualitatively it has been shown that this energy can be utilised in a gas turbine. Combustible gases can be produced underground on the coal ribs, but inadequate control of contact between the carbon faces and the gas-making fluids has so far prevented obtaining this gas above ground for more than a few days at a time.

A new installation has been constructed at Gorgas to facilitate additional investigation of the process of underground gasification. The "American" bed, which lies under the "Pratt" coal bed in this area, is now being gasified, and an electrical system of connecting inlets and outlets in the coal bed is being tried. The additional cover over the American bed and the greater distances to its outcrops is expected to be of help in preparing a system which will be much tighter with respect to gas leakage. The electrical system of connecting inlets and outlets should reduce site development costs greatly and eliminate all underground labour.

It is of interest to note that, as part of the first international conference on the underground gasification of coal, which was held at Birmingham, Alabama, in January, 1952, an inspection was arranged for delegates of this third underground gasification experiment.

The above article is based on the *Report of Investigations* 4808, which is obtainable from the Bureau of Mines, U.S. Department of the Interior, Pittsburgh, Pa.

Operation of Turbo-Supercharger Units

Period	Gas pressure turbine inlet, lb. per sq. in gauge	Gas temperatures, deg. Fah.				Adiabatic efficiency, per cent		Compressor operation			Ratio of air compressed to gas expanded through turbines	
		Entering cleaning train	Entering turbines	Turbine discharge				Discharge volume, cubic feet per min*	Discharge pressure, lb per sq in gauge	Overall adiabatic efficiency of two stages, per cent	Mol. of air per mol. of gas	Lb of air per lb of gas†
				First turbine	Second turbine	First turbine	Second turbine					
1	5·4	1051	840	—	—	—	—	995	7·5	44·5	—	—
2	8·3	1311	1130	—	—	—	—	1665	16·6	52·8	—	—
3	9·2	1377	1190	1127	1074	—	59·4	1850	17·3	45·8	—	—
4	9·3	1356	1190	1111	1088	47·4	48·4	1935	17·5	44·3	0·448	0·444
5	9·5	1217	1110	1024	1010	46·7	49·5	1940	17·7	35·4	0·445	0·443
6	9·7	1194	1090	987	970	54·7	54·9	1970	17·7	39·8	0·540	0·537
7	9·6	1214	1090	1004	985	51·4	50·3	1905	17·6	37·8	0·504	0·504
8	9·3	1220	1120	1028	1017	47·0	58·2	1800	17·2	40·5	0·472	0·474

* At 60 deg. Fah., 30in Hg., dry. † Corrected for moisture content

Sindri Fertiliser Factory

No. III—(*Concluded from page 370, March 14th*)

The fertiliser factory at Sindri, in India, which has now been officially opened, is designed to produce 350,000 tons of ammonium sulphate a year. It consists of four main sections: a power-house, a gas plant, an ammonium synthesis plant, and a sulphate plant. In its design and layout provision has been made to increase production in the future. The project is an example of co-operation between the Government of India and firms in this country and the United States.

The Ammonia Synthesis Plant

THE ammonia synthesis plant is laid out in a building which is some 66ft high and has a floor area of 5300 square feet. The flow sequence can be seen in the second part of the diagram on page 369.

Converted gas is drawn from its holder by the eight six-stage compressors, shown in another of our illustrations, and delivered to the purification and synthesis sections. The removal of the carbon dioxide and the remaining carbon monoxide is carried out between stages of compression, resulting in the gas having the correct proportions of hydrogen and nitrogen for the synthesis of ammonia.

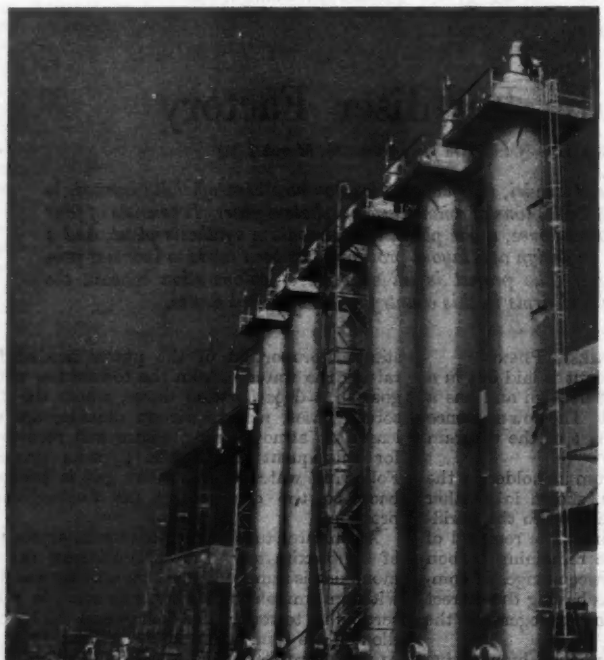
The carbon dioxide is removed by washing the gas with water in six packed, 75ft high, scrubber towers, shown in another of our illustrations. These towers operate at a designed pressure of sixteen atmospheres, and at the base of each is a motor-driven centrifugal pump, which delivers water to the top. Mounted on the same shaft as each pump is a turbine, which receives the descending water at the base of the tower and imparts to the pump a substantial proportion of the power needed for raising the water. From the towers the water goes to a degasification tower, where the dissolved gases, mainly carbon dioxide, are released at atmospheric pressure and recovered for subsequent use in the gypsum process. Following water washing the gas is brought back to the compressors for further compression.

At an interstage of compression at a pressure of approximately 120 atmospheres carbon monoxide is removed from the gases by washing with an ammoniacal cuprous solution in three scrubbing towers. The last traces of carbon dioxide are then removed by washing in three caustic scrubbers. The cuprous solution is circulated continuously through the scrubbing towers, where it absorbs the oxides of carbon, and thence through a regenerating system, where it is freed from the oxides of carbon, cooled by water, and further cooled by ammonia. The gas, which now consists of three parts of hydrogen and one part of nitrogen, except for traces of methane and argon, leaves the caustic scrubbers and passes through three separators

MULTI-STAGE GAS COMPRESSORS

to the last stage of compression, where it is compressed to 350 atmospheres for introduction to the synthesis system.

This compressed hydrogen-nitrogen mixture is delivered to the synthesis system and, after entrained oil has been removed in a filter, is mixed with the gases in circulation. The gases in circulation contain some uncondensed ammonia and unconverted hydrogen-nitrogen gases, and with the freshly added mixture go to four cold exchangers for precooling before entering the ammonia cooled condensers, where final condensation of ammonia from the gas stream takes place. This final condensation of ammonia from the mixture of make-up gas and circulating gas is characteristic of the process, and is responsible to a considerable extent for the long life and high efficiency of the catalyst. Leaving the condensers, the gas mixture flows back through the four cold exchangers, where the condensed ammonia is separated and drawn off into the ammonia storage tank. After the removal of ammonia the gas enters four ammonia converters, the main inlet of each being near the top, with a by-pass connection at the bottom, permitting regulation and control of the converter temperature. Each converter is of a special design with a built-in heat exchanger and is charged with a high-grade catalyst that promotes the combination of nitrogen and hydrogen at high pressure into anhydrous ammonia. Gases leaving each converter are cooled in the water-cooled primary condenser, where the greater part of the ammonia is condensed and removed from the separator as liquid anhydrous ammonia. Pressure is maintained during the synthesis flow by five recirculating compressors, each having its own filter, one unit acting as a standby.



CARBON-DIOXIDE SCRUBBER TOWERS

The anhydrous ammonia bled off from the ammonia synthesis system is passed to a weighing and storage section. Two horizontal measuring tanks are used to measure the quantity of ammonia produced and a let-down tank reduces the pressure of the ammonia. The refrigerated spherical bulk storage tanks, which receive the ammonia from the measuring tanks and keep the vapour pressure down to design limits, each have a capacity of 800 tons.

THE SULPHATE PLANT

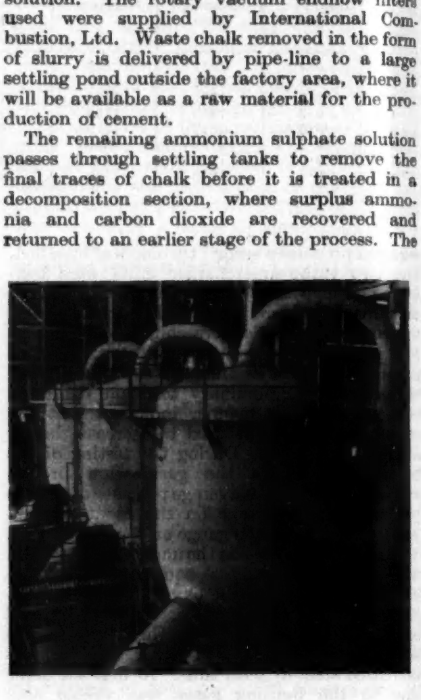
The sulphate process used at Sindri is based on that developed by Imperial Chemical Industries, Ltd., which made its experience available to the Chemical Construction Corporation so that there could be built a factory which would rely upon indigenous materials and not require the importation of sulphur. We reproduce a flow diagram of the ammonium sulphate plant.

Ammonia does not react readily with calcium sulphate, but ammonium carbonate produced by the reaction of ammonia with carbon dioxide, which is available as a by-product from the ammonia synthesis process, reacts with calcium sulphate.

Calcium sulphate or gypsum is received in "run-of-mine" condition and provision has been made for storing 100,000 tons under cover, which is sufficient for two months' operation. To assist the reaction the gypsum is crushed in reversible hammer mills before grinding in eight "Lopulco" mills, supplied by International Combustion, Ltd. Each mill is complete with circulating fans, cyclone dust collectors and bag filters, as well as drying equipment for removing excess moisture.

The reaction between ammonium carbonate and ground gypsum takes place in a series of vessels provided with stirrers. Thereafter standard principles of chemical engineering practice are applied to obtain the most efficient results. The magma from the reaction section is passed over two stages of filters operated in series to separate the calcium carbonate sludge or waste chalk from the ammonium sulphate solution. The rotary vacuum endflow filters used were supplied by International Combustion, Ltd. Waste chalk removed in the form of slurry is delivered by pipe-line to a large settling pond outside the factory area, where it will be available as a raw material for the production of cement.

The remaining ammonium sulphate solution passes through settling tanks to remove the final traces of chalk before it is treated in a decomposition section, where surplus ammonia and carbon dioxide are recovered and returned to an earlier stage of the process. The



EVAPORATOR UNIT

ammonium sulphate solution then passes into a storage tank ready for treatment in the evaporator plant.

The evaporator installation, which was supplied by Ashmore, Benson, Pease and Co., is of the well-known "Krystal" design and is the largest of its kind in the world. The plant is housed in a building covering an area of some 48,250 square feet, and the installation consists of three sets of triple-effect evaporators, making nine vessels in all. Each set has an external heat exchanger, liquor circulating pump, liquor and vapour lines.

To obtain the required output of 350,000 tons of sulphate crystals annually the daily consumption of the plant amounts to 3000 tons of feed solution, 600 tons of exhaust steam, 5,350,000 gallons of cooling water for the condensers, and 7200kW for driving the circulating and regulating pumps.

Each vessel is of stainless steel construction and comprises two main parts. The upper part, where evaporation takes place—known as the vaporiser—and the lower part, where the crystals form and grow, the suspension container.

The vaporisers are 12ft 6in diameter, the containers 14ft 6in diameter, and when mounted one above the other are 40ft high overall. In the containers the lower internal surface of the stainless steel is polished in order that the caking of crystals on the metal surfaces may be avoided.

Fitted inside the suspension container is a

central pipe, which guides the supersaturated liquor from the vaporiser (where supersaturation occurs) to the suspension container, in which there is a dense suspension of crystals. The supersaturation is released upon the crystal suspension, causing it to grow, and as the crystals sink to the bottom of the vessel, due to their increased weight, they are removed from the vessel through a salt catcher, which is a small vessel attached to the underside of the main vessel. Slurry pumps transfer the crystal slurry to the vacuum filters.

The pumps circulating the liquor in the vessels are specially designed so that they do not crush any of the crystals which may circulate through the system. These pumps circulate nearly half a million gallons of liquor per hour, the circulation being controlled by a butterfly valve fitted in the liquor pipe-line.

As shown in the diagram, vapour from each effect is carried by vapour lines to the inlet on the calandria of the following effect, and in the case of the last effect direct to a main barometric condenser and two-stage ejector. The crystals of ammonium sulphate as they leave the evaporator plant are separated in vacuum filters and then passed to three sets of rotary driers and coolers, supplied by Edgar Allen and Co. In each stream the ammonium sulphate enters the rotating drier, through which hot air is blown, and then through a rotating cooler of similar construction, in which atmospheric air is passed. Fans and cyclones are provided to recover the dry ammonium sulphate dust and return it to the belt conveyor.

The sulphate crystals from the drying and cooling plant pass through a system of belt conveyors to a large reinforced concrete silo. This silo, built to the design of Cementation Ltd., Doncaster, is the first of its kind in the Far East. It is in the form of a parabolic arch, 140ft span, 90ft high inside and 660ft long, and is capable of holding 90,000 tons of ammonium sulphate, equivalent to three months' output. The crystals are removed from the silo by the boom of a mechanical scraper or excavator, which feeds an underground belt conveyor delivering the crystals to an elevator tower, which supplies the weighing and packing plant, where the bags are branded, automatically filled, weighed and sewn. This plant is arranged so that ammonium sulphate can be despatched from the factory by rail at the rate of 2000 tons a day.

The pipework system used in linking up the various items of plant in the process works and in the power station involved the installation of some 80 miles of pipes varying from ¼in to 6ft diameter. The contract for this work was placed with Stewarts and Lloyds, Ltd., which manufactured and fabricated the power station pipework in this country, and supplied the materials for the process plant pipework which was fabricated and erected on site by Stewarts and Lloyds of India, Ltd. On the high pressure pipework all-welded Dawson joints were installed, and on the low pressure systems many of the joints were butt-welded, flanges being used for the most part on connections to plant valves and similar terminal points.

This project is evidence of successful team work on an international scale on the part of the United States of America, United Kingdom and India, and, as already mentioned, the layout of the plants and of the site has been arranged so that in the future the output of ammonia and ammonium products can be doubled.

Reorganisation of Airedale Works

The Airedale works of Kitson and Co. were taken over by J. and H. McLaren, Ltd., in 1945, to meet the post-war demands for oil engines. For the production of diesel engines considerable reconstruction of the old factory was necessary, and we give a short review of the development of the McLaren engines, together with a general description of the reorganisation of the site.

SMALL and medium-powered diesel engines and power units for a wide variety of industrial and marine purposes are being produced at the Airedale Works of J. and H. McLaren, Ltd., of Leeds. At the invitation of the company, we, together with other members of the technical Press, were able to pay a visit to the works last week to inspect the present organisation of the factory. This includes the site occupied by Kitson and Co., a firm which was one of the pioneers in developing the locomotive industry at home and overseas.

J. and H. McLaren, Ltd., was founded in 1876, and, at the Midland Engine Works, which was equipped to produce agricultural machinery, began to manufacture steam traction and ploughing engines. A period of steady development followed, and fifteen years later the firm extended its scope and began to build triple-expansion engines for electricity generating stations. For a number of years the firm had been constructing internal combustion engines, using petrol, paraffin and alcohol as fuel, but after being established for half a century the company decided to enter the rapidly growing diesel engine field. An agreement was entered into with the Daimler-Benz Company to manufacture, under licence, that firm's airless injection diesel engine. So a new era began and the efforts of the company were steadily switched from steam to oil power.

Two-to eight-cylinder units were designed and built, and many of these early models proved successful as propulsion units and for driving generating sets and compressors for naval applications, having passed the severe acceptance tests imposed by the Admiralty, including cold starting by hand under Arctic conditions. In addition to marine uses the engines were employed, with success, as prime movers for a wide range of industrial plant, such as excavators, road rollers and light locomotives. At the request of the Royal Navy lighter models were produced for the propulsion of launches, and the demand for more powerful engines elsewhere resulted in the introduction of units having a larger bore and running at increased revolutions per minute. The next major step in development was the adoption of the "Ricardo Comet" combustion head for the range of medium-size engines, "Mark M.R.," which developed 22 b.h.p. per cylinder at 1000 r.p.m., and were available as two, four, six and eight-cylinder units.

By the end of the last war it was evident that the production capacity of the Midland works was inadequate to cope with current demand and post-war requirements. Plans for expansion were brought to maturity when the adjoining works of Kitson and Co., known as the Airedale Foundry, became available, and the opportunity was taken to acquire this factory. In so doing, the company added not only some 12 acres of workshops to raise the total floor space available to 15 acres, but also trained works personnel to the existing labour force. The change over to diesel engine production in the newly acquired factory called for extensive repairs to old buildings, many of which still retain their wooden roof trusses, and the complete reorganisation of floor space, together with the installation of machine tools to meet the demands of planned production designed to satisfy post-war markets. In 1939 a labour force of 300 was producing ten engines per week; in ten years these figures had risen to 1400 and 200 respectively, while to-day the number of employees has increased to 1900.

The value of the increased floor space was almost immediately appreciated, for the shortage of fuel and power during the winter of 1946–47 had repercussions in factory output and created a demand for small standby power units. This demand was met by the production of a 55kW generating set driven by an "M.R.4" diesel engine of 88 b.h.p., and to-day the company manufacture a range of such generating sets including units of 27kW, 40kW, 55kW, 70kW, 85kW and 110kW capacity. It was interesting to note during our visit that six 55kW sets were in use for supplying power to the machine shop and elsewhere.

In conjunction with Fielding and Platt, Ltd., and Petters, Ltd., McLaren's redesigned an existing unit, and in 1947 commenced to manufacture horizontal Petter-Fielding four-stroke, single-acting, diesel engines. There are three single-cylinder models available: "Mark DH," of 13 to 16 b.h.p. at 650 to 800 r.p.m.; "Mark EH," of 21 to 27 b.h.p. at 500 to 650 r.p.m., and "Mark FH," developing 32 to 40 b.h.p. at 400 to 500 r.p.m. The latter engine is produced as a twin-cylinder unit and is rated at 64 to 80 b.h.p. over the same speed range. In association with the National Gas and Oil Engine Company, Ltd., J. and H. McLaren, Ltd., have developed the Petter-Fielding oil engine as a gas engine.

Engine design and production methods are constantly under review, and last year the "Ricardo Comet" head, with its precombustion chamber, was replaced by a direct-injection head, and the new series of engines are known as "Mark M." In keeping with modern trends, crank cases and sumps have been designed for fabrication, and units manufactured by this

LIGHT MACHINE SHOP

method are fitted to the two, three and four-cylinder engines.

General Description

The factory area is broadly L-shaped; starting at the toe of the short leg there are the offices and the heavy machine shop, then the cylinder block and head machine shop, the apprentice school and general stores. In the heel is a machine shop, a light machine shop and inspection bay, and opposite them are three assembly lines. The foundry, fettling yard and casting dressing shop occupy the first length of the long leg of the L, and proceeding towards the toe there are successively the "M" and "B" engine stores, the main erection shops, and finally the plate preparation, fabrication and press shops. A boiler-house contains four oil-fired Lancashire boilers generating steam at 100 lb per square inch for space heating purposes and domestic uses.

Unlike many modern factories which have been built to house particular production operations, the existing buildings have had to be adapted to production requirements which, in turn, had to be modified to suit the space available, so that the final arrangements are a compromise. We reproduce, opposite, photographs of some of the shops.

The foundry, which is centrally situated and has a capacity of about 40 tons per week, produces sumps, crankcases, flywheels and smaller components, such as water pump housings and governor carriers, while such items as cylinder heads have perforce to be purchased outside. All handling is done by overhead travelling cranes, and the coke-fired cupola furnaces have a capacity of 3½ tons per hour. Coke firing is used for the core stoves, and the weight of the heaviest casting normally produced is 3 tons. Large castings are shot blasted; and partly machined castings, which cannot be shot blasted, and small castings are cleaned by dipping in a deoxidene bath and then given a cold water running rinse followed by a hot rinse. After passing through the fettling yard the castings are spray painted and then pass to the machine shops.

The large castings, such as sumps, cylinder blocks and heads, and flywheels are forwarded to the heavy machine shop and the adjoining cylinder block and head machine shop. The equipment includes Cincinnati milling and planing machines, Kearns borers, vertical millers by Reed-Prentice, and a Colburn machine with a speed range of 2 to 38 r.p.m. for dealing with the heavy flywheels. Jigs are extensively used in association with Archdale radial drillers. Cylinder blocks are machined on an Ingersoll twin-head milling machine, and it was noted that the liner was pulled in by hand and that, for watertightness, a flat copper ring is fitted at the top of the liner and a rubber ring, of circular section, at the bottom. The cylinder block, liners and studs are tested to 60 lb per square inch with water at 90 deg. Cent. Hand grinding is used for seating the valves, and the cylinder head, after assembly, is tested up to a pressure of 1500 lb per square inch using paraffin as a medium.

In another machine shop the crankshafts of the various engines are ground and turned, and included among the equipment are Churchill grinding machines and a battery of Shardlow vertical lathes engaged on machining the crankshaft webs. This method of carrying out the work should be helpful in eliminating whip in the crankshaft.

A Kendall and Gent twin-head milling machine is used to mill the joint face, bearing keeps, support face and oil sump cover face, and a horizontal boring and milling machine, by Forges de Gilly, is employed in facing the timing gear end and flywheel end and in boring the crankshaft main bearings and also those for the camshaft.

The light machine shop has wide gangways, which allow the work to be progressed through the shop to the inspection bay, and batteries of capstan machines which mass produce the smaller components. The heat-treated H-section steel connecting-rods are face milled, and an Asquith multi-drill machine drills the lubrication oil hole through from big-end to

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small-end, while other machines turn the bronze bushes for the small-end bearing and machine the gunmetal white-metal-lined big-end bearings. In other parts of the shop machining operations were being carried out on the aluminium alloy castings used for such items as rocker gear covers, governor gear casings, big-end covers and dip stick funnels. Gear cutting is carried out by a machine built by Sykes, Ltd., which is capable of cutting 102 teeth in a blank in forty-four minutes.

There are two erecting shops; in one is an "M" engine erection line, a specialised "B" engine machine line, and a bay for the assembly testing and packing of 55kW sets. In the main erection shops the space is devoted to the erection of "M" marine engines, "B" engine sets, Petter-Fielding horizontal engines, electricity generating sets, and to final testing and packing. The assembly system adopted is the static roller track method, in which sub-assemblies are built up and are fed to points along the main conveyor line, the delivery point being arranged to suit an ordered sequence of erection operations. There is an adequate stillage capacity for the storage and supply of components, and column-mounted cranes which are placed at points where the heavier assemblies have to be swung on the main conveyor line. The test bay runs right across the shop, and the Petter-Fielding engines are rapidly brought up to speed and load. Then the single-cylinder engines are run at full load for three hours, followed by a 10 per cent overload for half an hour, while the twin-cylinder engines have a full-load test of four hours.

Among the other departments visited were the fabricating shops in which mild steel plate is sheared, rolled and bent, while special shapes are cut to template by oxygen cutting machines. In the welding shop crankcases, sumps and cylinder blocks are prefabricated, and after construction are stress relieved in an annealing furnace. Air receivers of 3, 5 and 11 cubic feet capacity are fabricated in the department, and the domes for the receivers are formed in a hydraulic press.

The company is able to obtain the necessary number of skilled personnel to maintain production, but, like many other engineering firms, it runs its own apprentice school. Here some eighty-five selected boys from local schools are given five years' training. For the first six months of the course the apprentices spend 50 per cent of their time in their own workshop, 10 per cent in the works, and the remaining 40 per cent is divided equally between the apprentice school and a technical school. This preliminary period serves as a measure of the boys' abilities and their future training is arranged accordingly.

The social amenities have not been overlooked and a gallery of one of the machine shops has been converted into a social centre which contains a games room and a large hall, equipped with a stage, suitable for dances, concerts and for the presentation of films.

British Standards Institution

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Basic Engineering Standards and their Place in Design

By CAPTAIN G. C. ADAMS, R.N. (ret.) A.M.I.Mech.E.*

In this paper, read before the Institution of Mechanical Engineers on March 14th, the argument is developed that the detailed design of the parts of a mechanism demands a logical approach. The designer should state on the drawing, in the simplest possible terms, what he really wants. The necessary range of basic (or abstract) engineering standards, both for him to achieve this aim and to provide for economic production, are given. The basic standards cover definitions, geometric analysis, ultimate standards of size, basic sizes, limits and fits, measurement, surface texture, drawing practice, standard forms (for example, screw threads), and standards of design. Their nature and scope are examined in general terms and some of the main compromises necessary are discussed. We print here some extracts.

The Construction of the Basic Standards

Basic Sizes.—Linear basic sizes are usually and conveniently associated with limits and fits, but the general subject covers a wider field and is properly considered separately.

Taking simple linear basic sizes first, these are the starting point in finding the limits of size for a fit. They are also a guide to the sizes to be selected for any purpose, when it is desired to select a size which is likely to be commonly used. Their object, in fact, is to ensure that as few sizes as possible are used, and that the number of sizes of tools and gauges is also kept as small as possible.

In Britain, no real agreed series exists on the inch system. A simple series of binary fractions has been commonly arrived at in, for instance, standards for tools and for many articles. There was a tentative agreement to use the American "Preferred Number" fractional series. There is also a tendency to use some kind of decimal series. It is not proposed to argue the merits of the fractional as against decimal series, or of a preferred number series as against a plain binary fractional series. There is an excellent British Standards Institution report on the subject (Sears, 1950)† which covers most aspects of the use of preferred numbers. Attention is called, however, to the convenience of a binary system for most design purposes. Halving is the simple, natural procedure and for many purposes gives more convenient increments of size than does the preferred number series.

The object of recommending a series of basic sizes is to reduce the number of sizes used and therefore of the tools and gauges. If the designer were concerned with rather crude mechanisms in which space and weight were of small moment, he might feel content with such a series of sizes as . . . $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, $\frac{7}{8}$, 1 . . ., and seldom find it imperative to go outside it. Steps of $\frac{1}{4}$, however, are obviously too large for many purposes in general engineering. Steps of $\frac{1}{16}$, in this range of sizes, would be far more suitable and, often, almost entirely adequate. In almost any precise form of design, smaller steps still would be needed and, when space and/or weight are very important, the designer may be very closely circumscribed indeed.

It is very commonly argued that such a series as that in steps of $\frac{1}{16}$ will meet a very large proportion of the sizes needed in engineering, and that the remaining "special" sizes needed are very few in any organisation. There is a great deal in this argument, but it is seldom realised how many different sizes are likely to be written down if no guidance is given. In the aggregate, the number is vast, and in some branches of design such special sizes are in the majority. An obvious extreme example is a rifle or machine gun. Here weight is of first importance and the designer must remove any metal surplus to strict requirements of function and safety. The starting point for size in the design, the size of the round, is arbitrarily determined by functional needs, and the designer would be lucky if he succeeded in using more than an odd size from the above $\frac{1}{16}$ series in the whole design.

The author analysed a list of plain "go" plug gauges, which was probably the largest ever prepared. It covered a vast range of products, and bore internal evidence that a conventional fractional series of the type discussed had been freely used in design. In spite of this, the number of sizes of gauge used was incredibly large. There were over 300 sizes between $\frac{1}{8}$ and $\frac{1}{4}$, that is, at the rate of 2600 per inch. At 1in they were at the rate of 1000 per inch, and at 2in at the rate of 500 per inch. Very similar absurdities appeared in two other large lists examined. It is very strongly held that this kind of fault will continue unless adequate guidance is given. Basic standards are not concerned with only one class of engineering, but with engineering as a whole.

The solution is easy, and, in principle, is of profound importance to the future of standardisation. It is to write down the series in a number of choices, say, first, second, third and fourth choices. For instance, a crude and simple series might be of the type given in Table I.

Table I.—*Series of Choices*

1st choice, in	2nd choice, in	3rd choice, in	4th choice, in
$\frac{1}{8}$		$\frac{17}{128}$	
	$\frac{9}{64}$		
$\frac{7}{128}$		$\frac{19}{128}$	
		$\frac{21}{128}$	
	$\frac{11}{64}$		Nearest 0·005
$\frac{1}{4}$		$\frac{23}{128}$	
		$\frac{25}{128}$	
	$\frac{13}{64}$		
		$\frac{27}{128}$	

The $\frac{1}{128}$in and $^1/_6$ in values are inconvenient, since they are five and six-figure decimals, and would probably be replaced by some simple decimal value in any actual series. At some point above $\frac{1}{16}$in size, the first choice increment would become $\frac{1}{32}$in and the columns would move to the right. The second choice would be $\frac{1}{64}$in, the third $\frac{1}{128}$in, and the fourth probably in 0·01in increments. At some further stage, the first choice would be in $\frac{1}{32}$in increments, and so on.

The point of this arrangement is that the number of choices actually used in any one design office can be conditioned to the class of work. It takes no great intelligence to learn to use always the highest choice which can be used, However, the design office which needs a third choice once a month will still be using the same sizes as does the designer who uses one once a day. In the aggregate, the reduction in the number of sizes can be immense. Since these are definitely canalised, any growth in closer types of design will be reflected in the self-creation of standard ranges of tools and gauges, which in turn will fall into natural "choices." This is a very simple example of how standardisation of articles can, and should, be the natural outcome of rational design.

The difficulty at present is that the designer cannot be rational without the guidance given by such standards as that for basic sizes. A large number of series can be constructed, all having merits and none being perfect. The time has long passed for fighting about which is the best, and also for one to be published which is sufficiently large to cover all reasonable needs of all engineers, now and for some time to come. Standardisation must always look ahead and must not be parochial. The interest of the individual is not the only interest.

Another kind of linear basic size occurs in the various sheet metal and wire "gauges." There is a tendency at present to try to simplify these. There is also a tendency to ignore gauges for sheet metal and strip, and to order to any appropriate size in thousandths of an inch. Where large orders are concerned, this causes no inconvenience to anyone, and no "gauge" series is needed. There are, however, many small users to whom a "gauge" series, in effect a first choice series, is a convenience for designs, orders and stocks. There are other fairly

* Member of the Ordnance Board, Ministry of Supply.

† Sears, J. E., 1950 B.S. 1638, "Report on the Selection of Ranges of Types and Sizes (Preferred Numbers)," British Standards Institution, London.

obvious conveniences in having such a first choice series, and this illustrates that such a standard can be justified even if it is regularly, and legitimately, ignored by many of the biggest users.

In principle, recommended basic size series should be framed for other than linear dimensions; for example, angular sizes. The need here is very much less, and the size used is perhaps more often determined by function. However, there is little doubt that a series could be prepared, at least for angles of taper, and that it might reduce unnecessary variation.

It is common practice to determine series of sizes, such as a series of horsepowers for electric motors for some type of use. Here the $\sqrt{10}$ preferred number series forms an excellent guide to the selection of sizes in suitable approximated values. All such series are of the nature of recommended basic sizes.

Series of articles, such as nuts and bolts and ball bearings, naturally arise, or should arise, from the basic linear sizes which should control their important functional dimensions.

Limits and Fits.—Engineers have long used, misused, or ignored one or more systems of limits and fits. Confusion is considerable, argument is fierce, and much paper has been covered; but the subject is at last being exposed in its full complexity. This is not the place to argue the merits of this or that compromise, but rather to point out the fundamental principles and the main compromises they entail. To do this in a short space, it is necessary to assume some knowledge of the subject and a reasonable acquaintance with the system of either B.S. 164 or the International Standards Association.

The object is to provide a systematic series of fits, so that as few as possible different limits of size will be stated on drawings. This will reduce the number of tools and gauges required. An alternative, and/or subsidiary, use may be to provide a series of fits which, for varying basic size, provide a similar functional result. These two uses may, or may not, be compatible.

It is becoming common to hold that the designer should state on the drawing the maximum tolerance which the geometry, or function, of the design will permit. In principle, this is precisely opposed to the object of using the minimum number of limits of size. There must be a first-class compromise at the outset, and the immense field of engineering will still demand a range of fits which can be achieved only with an adequate "choice" system. Much of the neglect of published systems in the past has been due to their inadequacy for more than a limited purpose. Great attention must be given to simplifying the presentation of any extensive system.

For convenience, a hole basis clearance fit will be considered, for which the conventional diagram is shown herewith.

The basic size having been selected, this will be made the maximum metal limit of the hole. This leads to tool economy. The allowance (minimum clearance in a clearance fit) must then be selected and subtracted from the basic size to determine the maximum metal limit of the shaft. This is the design size of the shaft on a unilateral system. The size of the allowance is determined by functional, and/or geometric, considerations. Its variation with basic size must, therefore, be based on some formula connected with function or, alternatively, enough allowances must be provided for the designer to be able to select an adequate compromise at any particular diameter. Certain sections of very free fits can conveniently be associated with constant allowances over a considerable range of diameter. The problem is further complicated because there is very little real knowledge of what extremes of fit are functionally satisfactory.

The next step is to allocate tolerances to hole and shaft, within the remaining space permitted by the safe maximum clearance. The magnitude of the tolerance is directly associated with ease of machining. The relative disposal of available tolerance between hole and shaft will depend upon which is the more difficult to machine. This varies with circumstances, and, over certain ranges of diameter, it may be desirable to have duplicate fits, as regards clearances, which alternatively give the larger tolerance to the hole and to the shaft. Account should also be taken of different machining processes, for example, most systems give few fits suitable for milling, slotting, &c. The formula for computing change of tolerance with basic size must therefore be associated with ease of machining. It is fairly certain, however, that it must change at intervals, since normal processes will also change.

It is obvious that we are faced with making big compromises on an inadequate basis of real knowledge. If the standard is to be widely used, it must either be very simple and rudimentary, such as the current recommended procedure in the United States, or sufficiently detailed to cover all reasonable requirements of engineering. It must, therefore, contain a lucid, simple explanation of principles and a clearly laid out "choice" system. Its main features are likely to be:—

(1) Primary concentration on the common ranges of size, perhaps in three separate ranges, such as up to $\frac{3}{4}$in, $\frac{3}{4}$in to 2in, and 2in to 4in. More than 80 per cent of all basic sizes are under 4in.

(2) Recognition of the functional nature of allowance and separation of the choice of allowance as far as possible from that of tolerance.

(3) Introduction of constant allowance series of fits for certain types of very free fit.

(4) Adequate selection, with choices, and indication of any particular fits which are known to be suitable for specified purposes over specified ranges of size.

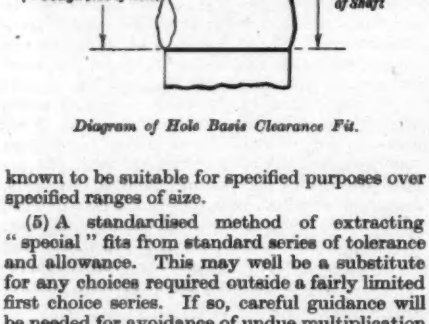

Diagram of Hole Basis Clearance Fit.

(5) A standardised method of extracting "special" fits from standard series of tolerance and allowance. This may well be a substitute for any choices required outside a fairly limited first choice series. If so, careful guidance will be needed for avoidance of undue multiplication of fits. It is probably safer to tabulate at least second choice fits.

The International Standards Association's system goes a long way on this road to perfection, but is capable of much improvement, particularly as regards simple exposition. Even if "a Solomon" arises to complete the desirable compromise, there are still difficulties in the way of interpretation and use. There is at present no clear conception of the real meaning of a limit of size or of the nature of interchangeability. It is usual to talk of a limit of size as if it were a hard line in a graphical representation of a fit and a clear-cut limit to the size of parts actually made. In fact, it is a more or less hazy zone of size. The first haziness arises from error of measurement. This is nominally small, though in the past the user of "inspection" gauges may have made the zone up to 20 per cent of the work tolerance outside the limit. A "Standard of Measurement" can clarify this, in principle, though it cannot cater for fortuitous error.

The real haziness is introduced when, as in some modern thought on the subject, account is taken of the statistical chances of mal-assembly. It can be shown easily that tolerances can be increased, and allowance reduced, to a considerable extent, without any large risk of mal-assembly outside the true functional clearances, where there is random assembly of large numbers. This is a highly rational argument and extremely logical in relation to large-scale assembly. However, a fit conditioned to this idea would, in principle, be unsuitable for small-batch production or for the provision of strictly interchangeable spares. The designer is thus required to assess, not only the functional fit but also the level of interchangeability acceptable in the specific conditions of use and production.

A similar statistical haziness arises if acceptance inspection is carried out on a basis of sampling by attributes, using limit gauges or the equivalent. It is then very easy for the effective limit of size to become extremely vague.

In the manual on "Dimensional Analysis," it is recognised that there is more than one degree of interchangeability. Strict, or universal, interchangeability is dependent on every mating part, whenever or wherever made, lying within certain limits of size fixed in relation to the ultimate standard of length. In principle, no risks of mal-assembly are permissible but, obviously, many degrees of risk are acceptable and many are regularly taken. In the extreme, we come to the alternative conception of "local" interchangeability, which lays stress on the maintenance of clearances which determine function, rather than rigid limits of size which determine strict interchangeability.

The current trend is to try to talk about "interchangeability," and to ignore the fact that its strict meaning is regularly compromised in practice. If we are to apply the very valuable statistical argument to limits and fits, we must clear the air and recognise the effect on interchangeability. If there are enough fits available, and/or if we are prepared to compromise severely with the principle of giving maximum tolerance, it will be possible for the mass assembler and the batch producer to use different fits for the same functional purpose, if necessary. The batch producer's fit can also be that for large production of articles, in which the need for strict universal interchangeability must be observed.

It will be seen that the biggest difficulty really lies in deciding how much attention must be paid to giving the largest possible tolerance for production. The Service designer takes this very much to heart, since he knows that much of his work will go, in time of war, to firms whose plant is barely good enough. From a precisely opposite point of view, many well equipped firms prefer to cut tolerances in favour of a strictly limited tool and gauge programme. It will be noted also that reduction of tolerance leads to increased wear life, and this alone can cause a big diversity of practice.

The problem is very complex. Before it can be solved satisfactorily the main objects in view must be examined and agreed. Account must be taken of design problems in general, and not merely those of the designer of high-grade long-lived machinery. It is unlikely that any general solution will arise until the main principles, and also those of geometric analysis, are more widely appreciated.

Drawing Practice.—This standard consists of definitions of how to express particular requirements on the drawing, so that the same thing written on the drawing always has the same meaning. There must be enough defined methods to express all the requirements that are commonly written down. It must be clearly understood that anything outside this range must be so written and explained that no ambiguity can arise.

Much attention has recently been paid to this matter and a great deal of argument has ensued. Much of the argument can arise from a failure to appreciate why, and when, it is necessary to express certain requirements. The need for many forms of statement is not universal, and is often apparent only when the full geometric analysis is taken into account. A very complete system, however, is desirable, although it will not always be used in full. Many drawings can, and should, be very simple. It is just as wrong to put too much on the drawing as to put too little, though it may be safer to err on the side of too much.

It is important that a drawing should be clear and easily read. The more it is covered with notes, &c., the more difficult is quick appreciation of its main provisions. Most of the more complex detailed requirements affect only a limited number of the people who will use the

drawing, for example, tool and gauge designers. The use of many kinds of symbol may therefore be highly desirable. They present no difficulty, but rather possess advantages to those who trouble to understand them, and they do not obscure the main provisions of the drawing which are of primary interest to the majority of users.

It is quite clear that a proper system of drawing practice is an essential to the setting down of the rational drawing of a rational design.

Standard Forms and Series.—The typical example of this class of standard is that for screw threads. A modern and up-to-date specification is B.S. 1580 for the unified screw thread. The Standard defines the basic form, and it also lays down standard series of basic sizes and standard fits, giving all appropriate tolerances and allowances. The basic size for screw threads includes not only the basic diameter but the appropriate pitch (diameter/pitch series).

The table of special threads in B.S. 1580 is a very complete example of the use of choices, which has been systematically worked out from the design aspect of metal available. It gives three choices of diameter. With the first choice of diameter four pitches in two choices are offered, and with the second, three pitches in two choices are offered. The third is intended to use one of these same pitches, and almost certainly would require the finest of them. It may also be noted in the footnote at the end of the table that the third choice of diameters —up to 1½in— still awaits the issue of a British Standard for linear basic sizes.

The number of diameter/pitch combinations listed in this table looks large. The author checked the number of diameter/pitch combinations in an existing gauge list and, up to a diameter of about 1½in, found three to five times as many as are given in the whole of the Standard and special (first, second and third choice) series listed in B.S. 1580 for the same size range.

Similar types of standard exist for gears, splines, &c. They are abstract standards in that they represent no concrete article, and they are essential to any economical use of these various forms. They cannot be properly framed without many of the earlier standards mentioned.

Standards of Design.—The term "Codes of Practice" is sometimes used to cover standards which fall in the class of design standards. These standards can lay down very simple guiding rules to govern requirements on any design of the type in question, or they can be detailed. They may even lay down the typical detailed layout of the design and give data from which the appropriate sizes can be completed. Their function is to prevent unreasonable multiplication of differences of detail in articles for which fresh designs must frequently be made, but whose duties do not permit the use of a standard series of articles. An average example (B.S. 1951)† is not very detailed in guidance as to principal dimensions, but it indicates how to dimension a spring in accordance with its function, and recommends tolerances. The tendency of any such standard is to lead to economical design and to consistent requirements in the inspection of articles having a particular type of duty. Each new article tends to be only a detailed variant of a precisely similar design, so that manufacturer and inspector are faced with a straightforward and intelligible problem.

Local standards of this type are well recognised in many drawing-offices. It is remarkable how much unnecessary variation they can suppress. The mere fact of drawing up one makes certain also that the design has been well scrutinised, when some very curious faults and variations can be brought to light.

The Practical Effect.—If adequate basic standards are provided, the first need, or perhaps effect, is education. Many engineers, for instance, have never opened B.S. 164, "Limits and Fits"; or, if they have opened it, have quickly shut it, for the very good reason that it was of little use in their class of work. Many more have never read it thoroughly; if they had, they would have acquired some information, though no very deep insight, into the proper use of limits and fits.

There is no doubt that these standards must be fairly complex, at least to the extent of giving choices. They cannot be used properly unless there is intelligent appreciation of the intention behind them. Therefore they must contain an adequate, lucid exposition of the subject and a plan simply laid out for use. The prejudice must be finally discarded that a standard must give only information and not instruction; fortunately, it is already weakening. Simplicity is important, but this must not be confused with shortness and must not compromise efficiency. Simplicity in layout and clarity in presentation are of chief importance. Simple numerical values are highly desirable.

The author has frequently put forward proposals for choices, or other apparent complexities, only to be assailed by the argument that the designer, or draughtsman, cannot be trusted, or lacks the intelligence, to use them reasonably. This counsel of despair is gradually breaking down, and is unjust criticism of a generally intelligent body of men who are only too keen to act rationally if they are given the means. It is only fair to them, however, that the basic standards should be an integrated whole, properly explained and based on a rational geometric background. Nearly all of these standards interlock. Change of one is likely to affect another. It is quite essential that there should be proper co-ordination when they are brought up to date.

Once this is done, the way is open to improve the standards for articles. It is a misfortune of standardisation that it is almost compelled to occur too late, since if it starts too soon it may cramp design or deter progress. The result has often been rationalisation instead of standardisation. We have been forced economically to select the least bad, or most commonly used, of a heterogeneous collection of uncoordinated designs. The complication has arisen more from the details of design, such as sizes and tolerances, than from major differences.

It is here that a co-ordinated system of basic standards can help. The details of design will differ far less, the same basic sizes will be used, and so on. Thus can emerge standard articles which are a rational by-product of co-ordinated detailed design. The tendency, moreover, will be to produce ready-made standard series. The local standard should be the forerunner of the national, or international, standard, and it should be automatically of the right type.

The real economic value of the basic standards, however, lies in their effect on the non-standard article. There is far more to be saved on the production of the myriads of special design parts than by the standardisation of common articles. In regard to the large industrial organisation this may be an overstatement, but not in regard to engineering as a whole. In large-scale production, tools and gauges are required in considerable numbers, as consumable articles. The fact that for a particular job many are not "standard," or from a restricted range of size, is relatively unimportant. It is in small-scale and batch production that multiplication of sizes becomes most objectionable. Moreover, most big organisations have established local rules, customs, and standards, which lead to a locally-efficient approach to production details.

The plea made here is for the generality of users. Whereas the big user may gain little from improved and co-ordinated standards, the smaller user may gain a great deal. In the long run, all parties should obtain much improvement. To the Services, with their widespread sources of production, such standards are most important. For all the local efficiency shown, it is often most startling to observe the very great variation in detail as between similar firms. It is all very well for the big organisation to act intelligently—for its own good. Too many intelligent schemes are already operating, so that it daily becomes harder to co-ordinate for the benefit of the many The small user cannot set his own standards to any marked extent, and in the aggregate the small users form a substantial part of the whole.

The biggest single difficulty in standardisation is to find enough men with the experience and knowledge, who can also give enough time to the work. This is particularly true of the basic standards. The natural tendency also is to be parochial in outlook and each to regard his own experience as of paramount importance. These standards are all-embracing, and the widest possible outlook must be taken.

The present situation is that we have been "putting the cart before the horse" in standardisation. We have concentrated on standardising articles and have largely ignored the standards proper to the design of those articles. Reason demands that we set our house in order before it is too late. Let us explain and educate as we go; let us think of the many, rather than of the few; and let us provide a solid general framework rather than a limited compromise.

† British Standard 1726, 1951, "Guide to the Method of Specifying Helical Compression Springs" (British Standards Institution, London).

Institution of Naval Architects

THE Institution of Naval Architects will hold its spring meeting on Wednesday, Thursday and Friday, April 2nd, 3rd and 4th, on board the "Wellington," the headquarters ship of the Honourable Company of Master Mariners, Victoria Embankment, London, W.C.2. The meeting will open at 10.15 a.m. on Wednesday, and after the annual business has been transacted the gold medal and premiums will be presented and a presentation made to Mr. P. J. Shilham, who retired last year from the post of assistant secretary. Viscount Runciman of Doxford, the president, will deliver his address and then Mr. Basil Sanderson will present his paper, "Britain's Deep Sea Liner Trade, 1945–51." The annual dinner of the Institution will take place at Connaught Rooms, Great Queen Street, W.C.2, on Wednesday, at 7.15 p.m. At 10.15 a.m. on Thursday the meeting will be resumed with the reading of papers on "Merchant Ship Design—a Thought on the Future," by Sir Wilfrid Ayre; and "Changes in Ship Construction Methods—1850 to 1950," by Mr. Norman M. Hunter. In the afternoon at 2.30 p.m. the following papers will be presented to a joint meeting with the Institute of Marine Engineers:—"The Generation of Gas Bubbles at the Shrinkage Boundaries of Built-Up Crankshafts for Diesel Engines," by Messrs. S. Amari and E. Ando; and "High-Powered Single-Screw Cargo Liners," by Mr. W. H. Dickie. On Friday, April 4th, the last day of the meeting, at 10.15 a.m., Messrs. D. W. Lang and W. G. Warren will present a paper entitled "Structural Strength Investigations on Destroyer 'Albuera,'" and Messrs. J. A. B. Gray and F. E. Smith will read a paper on "Prediction of Thermal Conditions in H.M. Ships in Tropical Waters." At the afternoon session, which opens at 2.30 p.m., papers by Dr. G. Hughes on "Frictional Resistance of Smooth Plane Surfaces in Turbulent Flow: New Data and a Survey of Existing Data"; and by Mr. W. Muckle, on "The Scantlings of Long Deckhouses Constructed of Aluminium Alloy," will be read and discussed.

MODERN COAL PREPARATION.—During recent years, a number of coal preparation plants have been laid down in this country by Nortons-Tividale, Ltd., of Tipton, Staffs. In order to show the work which goes into the design, manufacture and erection of a modern coal preparation plant, and its operating sequences, the firm has now made an interesting sound and colour film. This film first gives a brief account of the factors to be considered when designing a coal cleaning plant and then shows the manufacture of some of the component parts in the firm's extensive works. Then there follows the main sequence dealing with the "Norton" jig washer and an animated flow diagram is interposed with series of views taken in a washing. With the aid of these diagrams and an excellent commentary, the whole sequence of operations is clearly shown from the time the coal arrives at the top of the shaft till it is loaded into wagons for despatch. The latter part of the film deals graphically with the link belt heavy medium processing plant for preparing large coal. We are informed by the firm that the film, which takes about half an hour to show, is available on loan, free of charge, to interested bodies.

THE ENGINEER

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MECHANISED AGRICULTURE

LAST week a three-day conference was held at Harrogate to discuss various aspects of mechanised agriculture, or "power farming," as it is often generally described. It brought together a large company of farmers, engineers, agricultural machinery dealers, contractors and advisers, and teachers from agricultural and agricultural engineering colleges. The discussions at the several conference sessions—and each day was a full one!—were initiated by short papers which reviewed very succinctly the present "mechanical" situation of this country's average-size farms, and two of which surveyed present trends in agricultural machinery design in Western Germany. The actual discussions in most instances took the form of question and answer, a method which was certainly successful in eliciting the opinions of the farmers and engineers and others present, and in providing for a free and frank exchange of their views.

On many an occasion recently, comment has been made upon, and some surprise expressed at, the rapid progress during the last decade or so of farm mechanisation. Certainly there is now greater appreciation than there was of the great contribution to that progress which has been made by engineers. The annual product of this country's tractor and farm machinery makers runs into many millions of pounds in value, and, in addition to meeting a regular home demand, it has become an increasingly important factor in our export business. Yet this high rate of mechanisation—which has involved much more than substituting the tractor for the draught horse—has brought problems to farmers and engineers alike, the solution of which has often been advanced by the growth of mutual understanding between "mechanisers" and "mechanised." Nevertheless, power farming requires to be economically, as well as technically, successful, and, as the first speaker at last week's conference put it, "In the present economic state of the country, there is a limit to what we can afford to do." There is also the view which was likewise reiterated at the conference, that in the last ten years there has been blindly pursued a course of mechanisation for mechanisation's sake, regardless often of the optimum deployment of labour and regardless, too, of the most effective employment of agricultural resources. If that is so—we do not subscribe to the view that it is—the responsibility cannot be placed wholly and solely upon engineers. They, after all, have done wonders in designing and producing, in a remarkably short space of time, a big variety of implements and machines, which has resulted in the fuller and more economical utilisation of the agricultural tractor. We do not overlook the fact that a full range, on any one farm, of the machinery now available, represents a large capital outlay, nor are we unmindful that much of that machinery is at work for only a brief period in each year. But the demand for so many machines has been created to a very great extent by the realisation that the internal combustion engine is a power unit which can achieve, economically and easily, far more than the laborious efforts of man and beast accomplished in a farming day which now seems long past! Meeting the demand for what sometimes appears to be an ever-increasing range of farm machinery does not imply, however, that perfection in design has been reached. British engineers have done and are doing a good job, but, as was suggested in a paper by Mr. McHardy, the organiser of the conference, there is room for improvement. It is not enough to design and produce a machine which is capable of performing its task; the designer and manufacturer must give just as much consideration to the question of that machine being maintained in good working order. Such matters, for example, as grease nipples hidden away in awkward spots and inaccessible cover plates which are difficult to remove, still call for close attention on the part of designers. Farm machinery has frequently to stand up to rough usage and, whilst sturdy construction is essential, it is equally essential that all designs should be kept to the simplest possible form. In recent years, as Mr. McHardy observed, there has been a tendency towards more and more complicated machines. It is a tendency which may quickly lead, not only to operational difficulties, but also to excessive maintenance costs.

The discussions at Harrogate last week revealed that such problems as those we have touched upon, and many others, are very much in the minds of farmers and engineers. They also emphasised another important matter. The state of this nation's finances makes it imperative that more and more food shall be grown at home, and one of the ways to that increased food production is undoubtedly through the judicious application of power on the land. Agricultural engineers know full well what is required of them in the export drive, and they are painfully aware that the shortage of steel and other materials is now beginning to curtail supplies of new machinery to the farms in this country. The more effective utilisation of existing machinery, therefore, becomes essential, and that is a task which invites still closer co-operation between engineers and farmers. Education in the handling and maintenance of agricultural machinery is making progress, though sometimes very slow progress. In this country, there are not nearly enough trained engineers to impart the required instruction. Some of the universities and technical colleges are providing courses which will go some way towards meeting the deficiency, and professional bodies like the Institution of British Agricultural Engineers are energetically and materially assisting. Moreover, a great deal of the educational work concerned with agricultural machinery is being undertaken by manufacturers and dealers. The outlay needed to increase that educational effort may be no small one, and the reward may not be nearly so great as is merited. But if engineers can help further to promote the more efficient use of the machines they provide, their labour will not be in vain.

THE LARGE FLEET CARRIER

THE striking power of a navy to-day is largely vested in aircraft, and the carrier is, in consequence, given the leading position in the fleets of both Great Britain and the United States. How long she will retain that position is a matter for speculation, in view of the rapid developments in guided missiles and the practicability of adapting atomic explosive for use in conventional weapons. It is indeed not unlikely that in the relatively near future guided rocket launching platforms will replace flight decks with a return to the capital ship—a smaller, faster and more expendable vessel than the battleship as we know her to-day. There is, however, no prospect of any immediate change, for the United States Navy has recently laid down a 60,000-ton carrier, and intends building nine more similar vessels. The Royal Navy, too, has now commissioned the 36,800-ton carrier "Eagle," and her sister ship, the "Ark Royal," is nearing completion. The details of H.M.S. "Eagle," now released by the Admiralty, go far to account for the sum of over £15½ million which this ship has cost to build. More powerful catapults—presumably the new steam-operated catapult, a British invention

—and an improved type of arrester gear, permit the operation of much faster and heavier aircraft than any previously catapulted from carriers. The generating plant consists of four steam-driven and four diesel-driven electrical generators, each with a 500kW capacity, connected to a 220V d.c. watertight ring main system. An emergency supply is available in the event of damage. H.M.S. "Eagle" is the first ship in the Royal Navy to have an automatic telephone exchange; and an integrated main broadcast system is fitted for passing general information, warning signals, &c., to all parts of the ship with, in action, a separate control of broadcasting to their own units by the various departments of the ship—armament, flight deck and hangar, &c. Among the amenities provided are electric galleys and laundry facilities, air conditioning in the messes and in important action positions, and twin lamp fluorescent fittings. The ship has a length of 803ft 9in, a waterline breadth of 112ft 9in, and a draught of 36ft. She is armed with sixteen 4·5in and sixty-one smaller guns.

These very large carriers are intended to operate the much larger and faster naval aircraft required to compete with shore-based aircraft on equal terms. The Russian surface fleet, with its three old battleships and some fifteen to twenty modern cruisers, will not present a serious menace in view of the overwhelming superiority of the N.A.T.O. Navies, and there would thus be little purpose in building large carriers for operations on the high seas. Their primary function is to take part in the kind of offensive which is always open to the belligerent holding command of the sea—invasion and capture of portions of enemy territory. For carriers, alone, can provide the necessary aircraft during landing operations, and while the N.A.T.O. Air Forces are establishing air bases on land. The size of the United States carriers, indeed, indicates that they will also carry bombers of considerable range and represents a triumph for the naval viewpoint. United States naval officers have consistently maintained that the bombing of hostile communications, submarine harbours and war potential factories and establishments is not a matter for Air Forces alone, but can be carried out more effectively by medium range bombers, with fighter protection, operating from carriers off an enemy's coast. In support of this view, they quote the Korean campaign, in which long range land-based subsonic bombers, such as the "B-29," have proved very vulnerable to attack from Russian "M.I.G." jet interceptors. But whether or not navies are to undertake strategic bombing, the large fleet carrier is an essential requirement at the present time, and her disadvantages—absence of docking facilities in likely operational areas, large numbers of eggs in one basket, &c.—must be accepted. With the "Eagle" and "Ark Royal," the Royal Navy has eight fleet carriers, but five of these will require extensive reconstruction and modernisation to make them suitable for operations in enemy waters. The modernisation of the remaining ship, H.M.S. "Victorious," is now well in hand. There are also four smaller but equally fast carriers of the "Hermes" class, which are nearing completion under the rearmament programme, and will be fitted with up-to-date installations. They will be quite effective for offensive work overseas, but casualties are likely to be heavy, and the total number of carriers available for this purpose would be entirely inadequate were it not for the twenty-seven Fleet Carriers of the United States Navy.

An offensive would be of no avail without the necessary protection for our sea communications. But, unfortunately, we are lamentably short of the smaller and slower class of carrier suitable for anti-submarine operations. It must be realised that the weight and size of both detecting devices and anti-submarine weapons now being installed in aircraft have increased to such an extent since the war that the modern anti-submarine aircraft will no longer be able to operate from the escort carriers which were used to such good effect in the last war. They were relatively small ships with slow speed and were constructed, mainly in the United States, on merchant ship hulls. The kind of trade protection carrier required in the future will be a vessel of the "Glory" class, which has done such excellent work in the Korean campaign. We have only six carriers of this class and three more partly constructed, all work on them having been suspended soon after the war. It may well be that the much lighter helicopter—which shows great promise as an anti-submarine aircraft—will help to provide an answer, but it cannot be easy for the Admiralty, at this stage, to decide whether to modernise more fleet carriers for offensive operations, or to resume work on the three smaller carriers for trade protection purposes. It seems that we cannot do both concurrently as long as we continue to accept so many foreign orders for merchant ships.

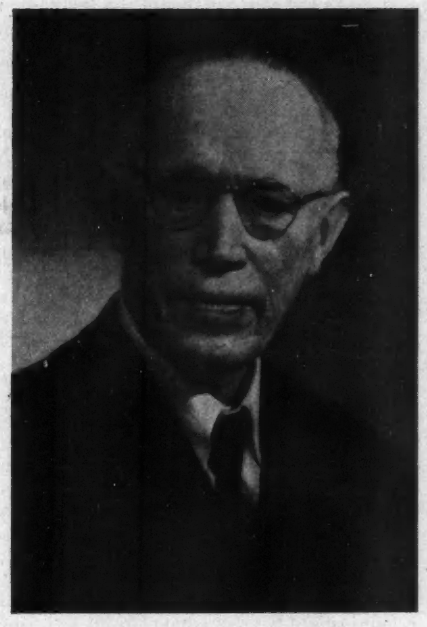
Obituary

DR. H. H. BLACHE

We have learned with deep regret of the death of Dr. H. H. Blache, which occurred in Copenhagen on Monday last, March 17th, following an operation. Dr. Blache, who was seventy-seven, had attained, during his long professional career, an international reputation as a distinguished marine engineer.

Hans Henrik Blache was born in Copenhagen on September 17, 1874. His father was Christian Vigilius Blache, Professor of the Royal Academy of Art, who was acknowledged in his day to be the most famous painter of marine subjects in Denmark. After graduating at the Royal Technical University of Copenhagen in 1896, H. H. Blache worked for a year in the Royal Danish Shipyard, as part of his national service. He then joined, in November, 1897, the shipbuilding and marine engineering firm of Burmeister and Wain, of Copenhagen, as a designer, thus beginning an association which continued, almost without interruption, until his death. To widen his experience, however, Blache, as a young man, spent a couple of years or so on design work with engineering firms in this country and in Germany. He returned to Burmeister and Wain in 1901, and for the next twelve years was concerned principally with the design and testing of reciprocating steam engines and turbines. On both the theoretical and practical sides of that work, Dr. Blache quickly revealed considerable ability.

In 1912, Burmeister and Wain completed the first ocean-going ship to be driven by internal combustion engines, and soon afterwards, Dr. Blache became the company's chief engineer. From then on, he took full responsibility for its engine design work and in particular for its development of the marine diesel engine. Early in the first world war, Dr. Blache designed a four-stroke, high-speed, light-weight diesel engine, which was installed in submarines built by his company for the Royal Danish Navy. It was eminently successful and many of its principles were subsequently embodied in much larger low-speed diesel engines produced to Dr. Blache's designs. In the early 1920s, the United Steamship Company, of Copenhagen, invited Dr. Blache to consider the development of diesel units for high-speed passenger ships, in which the engine space could be minimised as much as possible. His response was a trunk engine, incorporating the best of the design points of his submarine engines. There quickly followed the four-stroke, double-acting diesel engines of the



DR. H. H. BLACHE

kind first installed in the motor ship "Gripsholm," in 1925, and a few years later Dr. Blache achieved a further success with a two-stroke, double-acting engine of large horsepower, the design of which included central exhaust piston valves and the use of positive rotary blowers for scavenging. After these double-acting designs, there came the Burmeister and Wain single-acting, two-stroke engines with centrally-placed piston valves. Dr. Blache was also responsible for the application of engine driven blowers for the supercharging of four-stroke diesel engines, and for advances in methods of cylinder and piston cooling in large reciprocating engines.

Dr. Blache was appointed managing director of Burmeister and Wain in 1919, and maintained regular personal contact with manufacturers of his firm's diesel engines in most of the shipbuilding countries of the world. He relinquished the office of managing director in 1935, in which year he joined Harland and Wolff, Ltd., Belfast. He returned to Copenhagen in 1939, and in recent years had been almost wholly engaged in consulting work. For many years, Dr. Blache had participated in the work of professional and technical societies, not only in his own country, but also here. From 1915 to 1936, he was chairman of the Danish Society of Marine Engineers and Naval

Architects, and for a number of years served as chairman of the Danish National Committee of the World Power Conference. Dr. Blache's many papers to engineering societies in various parts of the world included a number presented to institutions in this country. Among them may be recalled a paper to the Institution of Engineers and Shipbuilders in Scotland, in 1925, on "The Latest Type of Burmeister and Wain Diesel Engine,"; one in 1931, to the Institution of Naval Architects, on "The Present Position of the Diesel Engine for Marine Purposes," and one to the Institute of Marine Engineers, in 1936, on "The Burmeister and Wain Two-Stroke Cycle Engine."

Last year, on the recommendation of the Danish Institution of Civil Engineers, Dr. Blache's work was recognised by the award of the James Watt International Medal "for his contributions to the advancement of mechanical engineering, and particularly for his pioneer work in the development of the large marine diesel engine." The medal was presented at a meeting of the Institution of Mechanical Engineers in London, on May 4, 1951, the citation accompanying it acclaiming Dr. Blache as "a brilliant engineer of great courage and resource, backed by sound technical judgment." On that occasion, Dr. Blache was elected to honorary membership of the Institution of Mechanical Engineers, and delivered a James Clayton lecture, entitled "Stages in the Design of the large Burmeister and Wain Marine Diesel Engine." Dr. Blache was created a Knight of the Order of Dannebrog in 1921, and was later decorated with the Silver Cross of the same Order. In 1934, he was appointed a Knight of the Swedish Order of "Nordstjernan."

J. H. HARLEY-MASON

It is with regret that we have to record the sudden death of Mr. John Harley Harley-Mason at his home at Datchet on Tuesday, March 11th. Mr. Harley-Mason was born on December 8, 1877, and following his education at Brighton Grammar School, was trained under Mr. Maurice Wilson at the Crystal Palace School of Practical Engineering. He was appointed an assistant at the firm of consulting engineers, Hassard and Tyrrell, in Victoria Street, London, in 1898, and in 1907 became a junior partner. Three years after, in 1910, he joined the staff of Perry and Co., public works contractors. As contractor's engineer with that firm, Mr. Harley-Mason, amongst a number of other works, was engaged in the construction of the 1800ft long ferro-concrete jetty at Tilbury, which is double-decked for trains, 10 miles of line for the Great Western Railway, and the subways at Elephant and Castle and Blackfriars. When Mr. Charles Rowell died he became chief engineer to the firm. In 1922, Mr. Harley-Mason secured the appointment as new works assistant on the staff of the Underground Railways, and in January, 1938, became new works engineer of the London Passenger Transport Board. He remained with the Board until December 31, 1942, when he retired. During his twenty years' service in connection with London's transport, Mr. Harley-Mason was responsible, under the civil engineer, for the western extension of the Piccadilly Line; new stations at Hammersmith, Aldgate East and King's Cross, and the civil engineering work on the Metropolitan Line's improvements scheme. He was also responsible for the depots at Morden, Northfields and Grange Hill. He was a member of the Institution of Civil Engineers and a Fellow of the Royal Geographical Society.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

ASSESSMENT OF LOCOMOTIVE PERFORMANCE

Sir,—In reply to Mr. E. C. Poultney (February 8th, page 216), I am afraid that analysis of "A3" cylinder performance has not a very direct bearing on that of the "A4s," with which I have been exclusively concerned.

For three reasons, an "A4," at any given cut-off, will afford a diagram of substantially greater area. (1) Boiler pressure is higher, (2) pressure drop between boiler and steam chest is almost eliminated, (3) wiredrawing through the steam ports is reduced by the more favourable ratio of valve diameter to piston area.

Whereas an "A4" can run for long periods with steam chest pressure equal to boiler pressure, the former seldom rises above 205 lb per square inch on an "A3."

High-speed diagrams from 2751 are seen to be poor, owing to wiredrawing and large negative areas caused by premature compression. Lay-out of the L.N.E.R. valve gear was similar to that of the G.W.R. "Castle" class, and "Caldicot Castle" displayed comparable disabilities under test, although ratio of valve diameter to piston area was more favourable.

British designers have tended to turn a blind eye to throttling at admission, and we have recently seen the extinction of an experiment, with sleeve valves, which might have made a notable contribution to cylinder performance. Foreign practice is less conservative.

My estimates of cylinder horsepower were arrived at by means of a formula incorporating a generic constant for long-lap valves. This constant gives figures approximately equal to those indicated on "Royal Scots," but there is reason to think that this class benefits from a cylinder performance above the British average. The unusually large lead would contribute substantially towards attainment of a high mean pressure.

At 75 m.p.h. and 20 per cent, the best outside diagram from 2751 exhibits a m.e.p. of 45. It is therefore not impossible that an "A4" might sustain a m.e.p. 15 lb higher at a speed 12 m.p.h. higher. All things considered, however, I could concede that a m.e.p. of 60 lb per square inch might be a little too flattering to the valve gear, which was identical with that of an "A3" and no doubt less efficacious than the other front-end components.

J. D. Munnion

Chelmsford
March 4th.

FUEL SUPPLIES

Sir,—The leading article which was published in The Engineer on February 29th is of great interest and importance, and I would make several comments on British Electricity Authority policy. They are not, from the point of view of efficient fuel utilisation, a matter which the Federation of British Industries so rightly stresses. In fact, in a letter to The Engineer, which was published in January, I emphasised the importance of extending the use of back-pressure generation, as well as oil engine peak-load sets. I feel, however, that it would be to public advantage if more information could be made available on policy regarding the incidence of power cuts. Nobody will deny that load-shedding is inevitable in present-day circumstances. However, in some towns, such as Brighton, a system of zoning exists and consumers in such areas know that they may experience cuts on certain days of the week, the day or days depending on the zone. This plan is certainly a step in the right direction.

I give one example of the difficulties caused by absolute uncertainty, and have in mind the case of a large steel works which experiences frequent cuts in the early hours of the morning prior to any likely peak-load period. Steam-raising plant of considerable capacity has been provided to meet certain requirements, with ample reserve, in case of non-availability of part of the plant, and also as a safeguard against power cuts. To maintain a reasonable gas balance in such works is always a tricky business. In this instance coke-oven gas is used for various purposes and any surplus sold to the Area Gas Board. On the other hand, the disposal blast-furnace gas presents a problem, and it is for this reason that it is used as far as possible for boiler fuel. It is not easy to bring water-tube boilers on to load quickly with this lean gas, although preparations to do so could be made quite easily were cuts to be expected at peak-load or other day-time periods. At this plant it is in the best general interest to purchase current from the grid, but the management is completely in the dark as to why power cuts occur when they do.

The brick industry presents some interesting problems in the matter of fuel economy. A continuous supply of current is demanded for the operation of kiln fans and for other purposes, but as power cuts must be expected, independent generating plants must be provided to safeguard essential requirements. One or more back-pressure steam sets will normally meet all the works power requirements, as well as providing the necessary heat for drying the ware, preparatory to its being set in the kilns. However, to-day the development of methods of extracting waste heat from kilns sometimes renders surplus the demand for exhaust steam. Engine plant has been scrapped and production is at the mercy of power cuts. It would seem that the development of the use of waste-heat boilers in this industry would point the way to a solution to the whole problem.

That the Ministry of Fuel and Power is fully aware of the necessity of making the best use of the National Fuel resources is indicated to the full in Dr. Roxbee Cox's Thomas Hawksley Lecture in 1951.

John Fox,
M.I.Mech.E.,

Hove, March 11th.

PHENOMENOLOGICAL

Sir,—I have been interested to read the recent discussion in your columns concerning the use of the word "Phenomenological."

I suggest that if it were transliterated into its original Greek characters it might look even more imposing, whilst it would certainly convey just about as much meaning to the average engineer as it does in its English guise.

L. F. Hobbs

Rickmansworth, Herts, March 14th.

THE GARRATT AND THE GAS TURBINE

Sir,—Replying to Mr. Johnson's letter in The Engineer, of March 14th, I can assure him we are in agreement with regard to the gas-turbine locomotive. I can quote one of my own articles, though I forget which: "The future is with the gas turbine." I think I was comparing it with the diesel-electric. I have not changed my opinion. This, however, did not mean that I pictured it monopolising the field to the exclusion of all other forms of motive power, but that it would play a large part in rail transport. The statement might be better put thus: "The gas-turbine locomotive has a great future"—in contrast to the steam locomotive of present basic design, which I imagine has next to none; its day is nearly over.

I admit Mr. Johnson's soft impeachment as

to my being a trailer of coats—that is the Irish in me, no doubt. The explanation of my remark about the difficulty in transferring my affections to the gas-turbine engine from the "basic design" steam locomotive lies merely in the adage about teaching an old dog new tricks. I was brought up in the age of the latter, and am too old readily to transfer my affections to its supplanter, upon whose character I have no wish whatever to cast aspersions. I am naturally sympathetic towards the steam locomotive—I always have been—I feel for it and with it when in its company, and can enter into its difficulties, and admire its work in a way I cannot imagine myself doing for a gas-turbine engine. To me a steam locomotive has a soul—a gas turbine has not. This attitude may be quite illogical, but there it is, and I cannot help it. I rather think it is natural, anyway.

A steam locomotive is responsive to the way it is handled to a greater degree than a gas-turbine-electric or diesel-electric, or so I presume—I have never watched one in operation yet. It needs skill to drive a steam locomotive and to bring out the best that is in it—though not nearly so much as the uninitiated would have us believe. Almost "any ass" can handle a diesel-electric after a lesson or two—he cannot a steam locomotive, though he does not need to be a genius or a wizard either. I do not know about a gas turbine; we shall see, but it probably comes into the same category as the diesel so far as the driving is concerned.

To sum up, the steam locomotive is like an old friend, whom one accepts as he is, with all his faults and failings—he is "loved and laughed at." Somehow, I can no more see myself loving a gas-turbine locomotive than a V-2 rocket—with which it has points in common. I could admire it, yes, but love it—I doubt it. However, to keep on good terms with Mr. Johnson, and quoting my previous letter, "I shall try, but . . . !"

EDWARD H. LIVESAY

Sheffield, 7, March 16th.

Literature

Production Forecasting, Planning and Control. By E. H. MACNIECE. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 94s.

IT is refreshing to read a book which deals with its subject in an original, if somewhat unorthodox, fashion, and undoubtedly Mr. MacNiece maintains the interest of his reader by giving him a number of questions at the end of each chapter, but before doing so he sets out a summary of the essential points covered, and finally, before passing to another phase, he provides what he terms a "discussion case," which gives experience in solving industrial problems. Such is the definitely unusual set-up of the book. The three distinct and yet allied subjects of forecasting, planning and controlling production are shown to be so dependent the one on the other that they can legitimately be dealt with together and closely interlocked in a single study—the principles of industrial management clearly defined. On reading the book it will soon be seen that it is written from the American viewpoint, while such terms as burden, stockroom inventory, and statements like "this book is primarily intended as a textbook for a one-semester course," or again, "every executive must know what is going on in his bailiwick," sound strange to engineers in Britain, who will, however, do well to see how important production matters are handled across the Atlantic. Indeed, many of the principles might be applied in this country.

The whole subject is covered in twenty-three chapters, in which, after clearly setting out the purpose and scope of his investigation and showing how good production management serves many interests, the author proceeds to deal with different kinds of production, and, after discussing manufacturing planning, factory planning and production planning, he turns to the important question of sales forecasting, and then shows how financial planning is helped by good production planning. He does not neglect such important matters as the loading of machine tools, the necessary recording and reporting on what takes place, while attention is paid to organisation problems, and two chapters are devoted to the value of co-operation between different departments. The necessity for aiming at level production, which in turn leads to stable employment, is stressed; indeed, we find the author is fully alive to the necessity for paying great attention to the human side of industry, one too often neglected when planning for production. Two chapters are devoted to the presentation of a typical problem and its solution, while a final one considers forecasting, planning and controlling war production, a subject to which we shall refer later. The book is well illustrated with charts and diagrams.

Three kinds of production planning are instanced: (*a*) project (or, we should say, single job), (*b*) batch, and (*c*) continuous production, and in connection with each the value of sales forecasting is urged, even though the difficulties of the latter are candidly admitted. Sales forecasting can be based on the considered opinion and experience of the upper staff, or on estimates given by salesmen, or on statistical sampling, or by a combination of them, taking into account the historical side. It is suggested that scarce raw material should be the basis for material purchase, and it is felt that there is wisdom in this, otherwise stocks of material that cannot at present be used will be built up unduly. Many questions are raised and discussed, such as whether the loading of machines involves too much work and could be dispensed with; but we agree with Mr. MacNiece that it is essential if good planning is to be ensured. Again, can production be scheduled by means of small cards on hooks representing individual orders? We feel there is much to commend such a system. The value of recording and reporting cannot be emphasised too much, and young British engineers might with advantage practise writing intelligent reports, leaving out nothing that is important, but avoiding all padding, and being definite, clear and concise. The author raises a note of warning against setting up cumbersome systems, and instances a case where dishonesty led to the launching of a system which proved far more expensive than any of the losses due to dishonesty. The value of quality control is rightly pointed out, in that it is designed to maintain standards during manufacture rather than detect faults after the event. That upward mobility in staff is essential may be regarded as axiomatic, and yet how often is it found that an otherwise successful member of the staff endeavours to keep to himself the detail of his work with a view to being indispensable, whereas he is thereby jeopardising his chances of promotion, while disorganisation will be apparent should he unavoidably be absent.

If the author can claim that production planning in America is ahead of that in other countries, Britain can justifiably aver that she has given a lead in war preparedness, in that long before the second world war a directorate of industrial planning was set up, which assessed the country's war potential and took steps in advance to train industrialists in the war work that would be entrusted to them. By this means transition from peacetime activities to the production of war material was relatively smooth. In the interesting chapter on war planning the author evidently has something of the same sort in mind, although he does not clearly indicate how he would co-ordinate the work under one authority. Placing of small educational orders in the days of peace might with advantage have been suggested.

Finally, in a well-considered and helpful treatise it is affirmed that success in forecasting and planning "depends upon attitudes and ways of thinking as much as upon the exercise of this or that particular skill." We agree and this book promotes thinking along right lines.

SHORT NOTICES

A.C./D.C. Test Meters. By W. H. Cazaly and Thomas Roddam. London: Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, W.C.2. Price 18s.—This book covers the principles, circuit design and construction of workshop grade instruments for testing of low power apparatus. It is intended to serve as a practical guide for the radio service engineer, laboratory technician and test-room staff. It opens with a chapter on moving coil indicators and proceeds to show how the same basic instrument is used for measurements on d.c. and a.c. circuits. There are separate chapters on a.c. voltage ranges and current transformers, and on instrument accuracy, with a section on the B.S.I. and its definitions of sub-standard and first grade instruments. As an example of what can be done, using the facilities of a "professional or good amateur workshop," the book gives a multi-range a.c./d.c. circuit design with instructions for building a practical workshop instrument.

A Complete Guide to the Building (Safety, Health and Welfare) Regulations: Statutory Instrument, 1948, No. 1145. London: The Royal Society for the Prevention of Accidents, 52, Grosvenor Gardens, S.W.1. Price 15s.—Intended for a standard work for ready reference to all concerned with building construction, this book will not only be of use to those actively engaged on the actual building task, but also to architects, engineers and others concerned first with design and later with supervision or consultancy.

The Regulations have what is possibly the widest application in industry generally of any made under the Factories Acts and this book provides a simple but complete guide for those whose duty it is to comply with the Regulations.

The relevant requirements are grouped under appropriate headings and the main sections covered are dates of operation, regulations revoked, definitions of terms, application of the Regulations and Factories Acts, obligations under the Regulations, appointments and personnel, examination, tests and records, notices, signs or marks, first aid, welfare and personal safety appliances, scaffolds, working places and access, excavation, demolition of buildings, chains, ropes and lifting gear, lifting appliances, hoists, machinery and general precautions.

Directory and Buyers Guide

THE 1952 edition of "The Engineer Directory and Buyers Guide" has just been published and one free copy is being dispatched by post to all subscribers on our lists. Arrangements have also been made for all regular readers who obtain THE ENGINEER through newsagents to receive a copy, which should be delivered to them with the current issue. Any subscriber or regular reader not receiving a copy should write to The Manager, THE ENGINEER, 28, Essex Street, Strand, London, W.C.2. Extra copies are obtainable at 5s. each, including postage.

Mechanised Agriculture

The rapid development of agricultural mechanisation in the United Kingdom during the last decade has presented many problems, not only to farmers, but to engineers and designers concerned with the production of tractors and farm machinery generally. At a three-day conference, held recently at Harrogate, opportunity was provided for full and frank discussion of some of those problems. This article summarises those parts of the proceedings which were of special interest to engineers.

ON Tuesday, Wednesday and Thursday of last week, March 11th, 12th and 13th, the second National Power Farming Conference was held in Harrogate. More than 200 people attended the conference, the company including, in addition to farmers, many engineers, machinery contractors and dealers, and representatives of the technical colleges and the National Agricultural Advisory Service. Mr. J. T. Beresford, vice-chairman of the development and education committee of the National Farmers' Union, was the chairman of the conference committee, and the many tasks associated with the general organisation were capably carried out by Mr. D. N. McHardy, editor of *Power Farmer*. The principal object of the conference was to provide opportunity to discuss in some detail the many problems arising from a fully mechanised agriculture and to seek out new ways of using power farming technique to the best advantage. All the papers presented at the conference kept in mind the requirements of the average farm—of, say, 300 acres or less—rather than those of the more extensive specialist holdings.

The first two papers read at the conference were entitled "What Can We Learn from America?" Their authors were Mr. H. T. Williams, head of the Ministry of Agriculture's economics branch, and Mr. E. C. Brown, an official of the National Union of Agricultural Workers, both of whom were members of the agricultural productivity team which recently reported on its tour in the U.S.A. One point emphasised by Mr. Williams was that, in striving for a high return on labour expended, the American farmer, set in a general environment in which labour-saving devices occupied a prominent place, had readily accepted the advent of the machine to the farm. Generally, the American farmer was extremely skilled in the use of a machine and was extremely mechanically minded. Nevertheless, he was very conscious of the economic and financial aspects of mechanisation. Mr. Williams suggested that farmers in this country might have been "too restrictive on the agricultural engineer and machinery manufacturer" and wondered whether farms could not be reorganised in order that better use could be made of the machines put at their disposal.

The papers of particular interest to engineers, however, were those presented on the second and third days of the conference. The first of them, by Mr. J. T. Beresford, dealt with the economics of mechanisation—a subject to which manufacturers as well as farmers must give close attention. Mr. Beresford pointed out that as most of the farms in the eastern half of this country were equipped for cash crops rather than grass, they were of a size and quality to support a relatively high degree of mechanisation. But he later suggested that, in the last ten years, this country had blindly pursued a course of mechanisation for mechanisation's sake, regardless often of the optimum deployment of labour and regardless, too, of the most effective deployment of natural agricultural resources. One of the speakers in the subsequent discussion emphasised, however, that a question of considerable importance in the country's agricultural policy was "not what was saved by mechanising, but what was lost by not mechanising."

Mr. Beresford's paper was followed by one entitled "How the Contractor Helps," by Mr. F. L. Sabatini, secretary of the British Agricultural Contractors' Association. Mr. Sabatini said that the man who farmed 100 acres or so must realise the need to conserve his capital and to use the machinery and skilled operators provided by agricultural contractors. The overhead charges where small acreages were involved so often outweighed the savings which a machine could secure. Mr. Sabatini added that the efficient agricultural contractor must be equipped, not only with the necessary machinery and implements, but also with some practical experience of farming. He argued that the ownership of expensive machinery and the employment of skilled operators by contractors was better than co-operation among farmers in the use of machinery, because an independent manager controlled movement from farm to farm and skilled engineers under the supervision of a contractor could maintain and operate the machinery more efficiently. This last point was taken up during the discussion by Mr. D. M. Walker, of the engineering department of the Shuttleworth Agricultural College, who felt that there was a need for contractors to provide a technical service in connection with various specialised farming operations.

IMPLEMENT CARRIER

Recent Developments in German Design

On Wednesday afternoon, two papers read at the conference dealt with recent developments in Germany in the design of agricultural machinery. The first was by Dr. H. Speiser, of Kiel University, and referred to Western Germany, where, the author explained, on account of the numerous small holdings, about 80 per cent of the farms were excluded from reasonable and thorough mechanisation. At the same time it was stated that to-day in Germany even the smallest farms were connected to the electricity grid and thereby benefited from a noticeable reduction in manual work. On the subject of implement development, Dr. Speiser's paper said that Germany lacked a very small sieveless combine-harvester with a cutting width of about 4ft, such as had already been produced in Sweden. On the small farms, therefore, the self-binder continued to be at the forefront of any development. A small binder was being produced which could be mounted at the front of a tractor. It could also be rear-mounted and could travel backwards! The paper mentioned also a drying apparatus using a roasting kiln, over which a kind of hay tedder moved slowly backwards and forwards and continually turned the material to be dried.

The other paper on German design was by Dr. H. von Hülst, of the agricultural staff of Göttingen University, who concerned himself principally with agricultural tractors. Dr. von Hülst acknowledged that quite a number of farming machines could be used on a co-operative or community basis, but that, he suggested, could not always be done with tractors. German engineers had looked for new and different solutions to make tractors meet the requirements of different-sized farms, but it was well known that the problem of building a smaller tractor could not be solved just by scaling down a large one. Dr. von Hülst went on to mention the German practice of equipping all tractors above 10 h.p. with diesel engines, which, it was claimed, had a number of marked advantages under present conditions in Germany. Diesel engines were more economical and diesel oil for agricultural use—which was less expensive than petrol—was subsidised.

Nowadays, buyers generally preferred full diesel tractors, and Dr. von Hülst commented that there was a trend towards a higher number of cylinders—up to four—to permit lighter designs of gearing and flywheel. In that respect, he observed, the unit system was rather interesting, as it cut down expenditure, not only at the factories, but in the number of replacement parts and servicing costs. Another observation made in the paper was that the air-cooled diesel engine was gaining more and more in importance in Germany. Its main advantages were its immunity to frost, its shorter warming-up period, and, consequently, a speedier attainment of working temperature. Furthermore, it was claimed that the detrimental components of diesel oils, especially those containing sulphur, could not cause so much damage with the higher working temperatures of air-cooled engines.

The four-wheel drive was next mentioned by Dr. von Hülst. He said that increased attention had been given to it in recent years. In all tractors of this kind, the four-wheel drive could be cut in and out, and, normally, the front and rear wheels were of equal size. In the construction of four-wheel driven tractors designers aimed to distribute 50 to 60 per cent of the weight on the front axle and 40 to 50 per cent on the rear, the weight distribution on orthodox tractors being about 33 per cent on the front axle and 67 per cent on the rear. Dr. von Hülst commented that tractors with four-wheel drive cost about 10 per cent more

than rear-driven ones, but amongst their advantages there should be included higher drawbar power and better steering stability under difficult conditions.

Dr. von Hülst concluded his paper with brief references to implements. In Germany, he said, implements were usually hitched to the rear of the tractor, but some tractors were arranged for centrally mounted tools. This latter mounting method, he thought, was to be preferred, although he stressed that it must be so designed as to make rapid change of equipment possible, for in Germany great emphasis was placed upon single-driver working. Finally, there was a mention of "implement carriers," which, Dr. von Hülst said, were a new development in Germany, and one which, it was hoped, would enable the demand for the mechanisation of small farms to be met. The accompanying illustration of an implement carrier built by Lanz conveys an idea of its general arrangement. Dr. von Hülst explained that the carriers included a rear-mounted engine and driving seat. The accessories—such as a plough, grain drill, beet and potato harvesters—were mounted to the frame at the front, which gave the driver a good view of the work without difficulty. A special advantage was that the rear wheels, as well as the front, were steerable, so that sideway sliding of the carrier on the shoulder of a hill could be avoided.

Electricity for the Small Farm

At the next session of the conference the chair was taken by Mr. F. E. Rowland, M.I.E.E., president of the Institution of British Agricultural Engineers, and Mr. C. A. Cameron-Brown, agricultural adviser to the British Electricity Authority, spoke on "Electricity for the Small Farm." Mr. Cameron-Brown admitted that, as present electricity supplies in this country lagged far behind demand, the proportion of farms supplied with electricity was not so high as in some other countries. Nevertheless, he asserted, an intensive study of farm electrification had been made and there had been developed here a degree of electrification and novelty of application not exceeded and rarely equalled anywhere else. Mr. Cameron-Brown then proceeded to deal briefly with the use of electricity for agricultural lighting, for dairy work, barn machinery, and grain and crop drying. He added the plea that in applying electricity to agriculture the information and advice, which were readily available, should be used to prevent good equipment being wrongly chosen for the particular job in hand!

The discussion on this paper was opened by Mr. Hamish Ferguson, secretary of the Diesel Engine Users Association, who referred to the existing difficulties of farms in remote districts becoming linked with the grid supply in the foreseeable future. He advocated the more extensive employment of oil-engined generating sets. Questions were also asked by other speakers about the possibilities of generating electricity by wind and water power. In reply, Mr. Cameron-Brown referred to the experiments with wind power which were being made, and said that the high overhead costs were a retarding factor. A similar difficulty was presented over electricity generation by water turbine.

Machinery Repair and Maintenance

The last day of the conference began with a paper by Mr. D. N. McHardy on the important subject of agricultural machinery repair and maintenance, the cost of which, he said, was to-day alarming on many farms. Mr. McHardy described the principal causes of breakdown and excessive wear, mentioning failure to give a machine a proper running-in before putting it to work, lack of lubrication, and vibration. To that list there was added neglect to protect implements from the weather by means of proper storage and the failure to clean implements after use. Saying that the farm workshop was a necessity to-day, Mr. McHardy agreed that its scope must be decided in relation to the mechanical ability available.

Implement manufacturers, the paper stressed, had an important contribution to make. It was not enough to design and produce a machine capable of doing its job. Designers should give equal consideration to the question of maintaining the machine in good working order. Accessibility for greasing and for overhaul was a prime essential, and was a matter which needed closer attention on the part of designers. More general use should be made of self-locking nuts, and many units might be restyled to eliminate reciprocating motions, which were often responsible for much vibration. In Mr. McHardy's view, however, the best way in which manufacturers could contribute to ease of maintenance was by keeping all designs down to the simplest possible form. Over the past few years there had been too great a tendency towards more and more complicated machines, a trend which seemed likely to bring in its train so many maintenance problems that the object of mechanisation might be defeated. Finally, the paper deplored the fact that education in the handling and maintenance of farm machinery was still in its infancy. There were not yet, Mr. McHardy said, anything like enough trained teachers, service men or indeed enough trained personnel in any of the sections concerned. That lack of training was at the root of the widespread evil of the too rapid wastage of farm machinery.

The concluding papers at the conference were on machinery for grass farms and equipment for root crops. They were presented by Mr. W. S. Shattock, a machinery adviser to the National Agricultural Advisory Service, and Mr. W. J. West, director of the Scottish Machinery Testing Station.

A Prestressed Concrete Bridge in Monmouthshire

The new Foundry Bridge which has recently been completed at Abertillery replaces an old steel bridge built in 1895 to carry the Newport–Brynmawr road over a deep railway cutting. By 1926 the original bridge, which was constructed of steel plate girders, had rusted to such an extent that it was condemned as unsafe and closed to traffic. As a temporary measure the structure was shored up with timber struts and reopened to limited loads in 1927. For various reasons, however, a new bridge was not built until recently.

The new bridge is 40ft wide, with a carriageway 27ft wide and two footpaths each 6ft 6in wide. Retention of the original pier gives it two unequal spans of 71ft 6in and 61ft 6in. Five prestressed concrete beams in each span carry a reinforced concrete deck slab. The beams, which are 73ft 6in and 63ft 6in long, were cast on the site. The Freyssinet system of prestressing was used, the longer beams being stressed with twenty-four cables and the shorter with eighteen.

While casting was in progress an investigation of the abutments and central pier was made and some improvements were carried out. A culvert which passed underneath the pier was diverted and the pier underpinned. At the western abutment it was found that there were layers of clay between the rock strata, and a mass concrete block was therefore constructed against the rock face, to transmit pressure direct to the lower stratum of solid rock. At the eastern end pressure piles were used to provide a stable foundation for the new abutment extension and wing walls.

Each of the main beams was moved into position across a temporary track and was then moved sideways into its final position by being hung from portal frames erected on the abutment and on the centre pier. Transverse beams were cast between them, which were intended to act solely as stiffeners. After these stiffeners had been prestressed the formwork for the decking slab was erected and the slab concreted.

The whole of the work was completed in approximately twelve months. The cost of the bridge was borne jointly by the Monmouth County Council and the Ministry of Transport, Abertillery Urban District Council acting as agents for the county council. The consulting engineers were Wallace Evans and Partners, the general contractors being Sir Robert McAlpine and Sons (South Wales), Ltd., and the Vibrated Concrete Company, Ltd., doing the prestressing.

Epicyclic Gears*

By H. N. G. Allen, M.A., and T. P. Jones

No. II—(*Concluded from page 375, March 14th*)

Design

General.—The main differences between the tooth working conditions in epicyclic gears and parallel shaft gears are :—

(*a*) The surface stress between the internal and external teeth running together is less than that between two external teeth because the relative radius of curvature, which is inversely proportional to the stress, is so much increased. For this reason it is usually found unnecessary to case-harden the annuli used in epicyclic gears, even when the sun wheel and planet wheels are case-hardened.

(*b*) For a given size and number, teeth cut on an internal ring are stronger than those cut on an equivalent external wheel.

Epicyclic gears offer considerable savings in weight and space and higher efficiency compared with parallel shaft gears, and the co-axial arrangement of input and output shafts is also an advantage. These savings are due to the load being transmitted by several tooth contacts.

Load Sharing between Planet Wheels.—It is essential to ensure that the planet wheels do share the load equally. If torque is applied to an epicyclic gear with three planet wheels whilst it is prevented from rotating and one of the co-axial members is allowed to float, the tooth forces involved will move the floating member until equilibrium is obtained. This state of equilibrium will be reached when the tooth loads on all the members are equal.

Under running conditions the problem becomes more complicated, since it it impossible to manufacture components which are perfectly accurate. Very small errors can cause considerable accelerating forces to act, but by mounting the annulus flexibly in the gearcase, very good load sharing can be achieved. This has been proved by applying strain gauges to the fixed annuli of planetary gears running under load. The method consists of attaching a number of electrical resistance strain gauges to the outside of the annulus and measuring the strains produced as successive planets pass each gauge.

Hardened Components.—As the sun and planet wheels are small they can be hardened more conveniently and their distortion during hardening is not such a serious problem. It is said that the permissible surface stress may be varied as the square of the hardness number and when changing from an unhardened to a hardened material with an increase in Brinell number from 190 to 630, much higher values of the loading coefficient, generally denoted by K, than those shown in the table of comparisons are theoretically acceptable.

Any hardening process, capable of giving a reasonable case depth may be used for sun and planet wheels but the amount of distortion arising from the hardening process will affect the choice of the finishing operation applied to the teeth. In most instances, case hardening followed by gear grinding on any of the well-proved form or generating type of gear grinding machines is used for the hardened gear wheels of high quality industrial and marine gears in this country. In the future, induction hardening may offer a means of hardening, with distortion low enough to eliminate the necessity for any post-hardening process on the gear teeth.

One method of hardening gear teeth which is used in Germany is nitriding, and in its favour are the almost negligible amount of distortion which takes place, adequate case depth blending well into the core and high core strength. After nitriding, a slight "bloom" or softer layer is present on he surface to the depth of about 0·001in, but this can be removed by light lapping, which also gives a slight amount of tip and root relief to the teeth. Gears have been run very successfully without any post-nitriding process on the teeth and the authors have found that for comparable accuracy the teeth of gears which are hardened by pack carburising

* The Institute of Marine Engineers, Tuesday, March 11th. Abstract.

and oil-quenching must always be ground after hardening.

As the surface stress is so much less on the annulus, being, for a planetary gear

$$\left[\frac{1}{\text{ratio}-1}\times(\text{surface stress on sun wheel})\right]$$

advantage may be taken of the reduction in size offered by the use of hardened sun and planet wheels without the necessity of hardening the annulus.

Efficiency.—The losses in a gear are :—tooth friction losses ; bearing losses ; oil churning.

Tooth friction losses are approximately proportional to the tooth load and the pitch line velocity. As the components in epicyclic gears are small their pitch line velocities are low compared with those of parallel shaft gears running at the same rotational speed. This is shown in Table I. Where the planet carrier rotates in the same direction as the sun pinion, or the annulus in the same direction as the planet carrier, the relative pitch line velocity is less than the actual pitch line velocity. The product of the tooth load and the relative pitch line velocity is proportional to the "potential horsepower." It follows that since the tooth losses are proportional to the potential horsepower, the efficiency of a gear in which the potential horsepower is less than the transmitted horsepower will be higher than that of a gear in which these two are the same.

In solar gears the efficiency is exceptionally high because the potential horsepower is equal to :

$$\frac{\text{ratio}-1}{\text{ratio}}\times(\text{transmitted horsepower}).$$

Bearing losses are dependent on the size of the bearings and when the input and output shaft bearings are supplied in epicyclic gears they are small because no tooth reaction loads have to be carried. A lightly loaded 2in diameter bearing 2in long with a shaft running at 7500 r.p.m., lubricated by a medium turbine oil, will absorb about 1·5 h.p. In epicyclic gears it is often possible to eliminate the high speed sun wheel bearings, and it is also possible in some cases to eliminate one of the low speed shaft bearings. Under the above conditions, the only bearings in the gearcase are the planet wheel bearings and one low speed shaft bearing.

Planet Wheel Bearings.—One feature of epicyclic gears which needs special attention is the design of the planet wheel bearings. Plain or ball or roller bearings may be used according to circumstances.

The authors consider that white metal is the best bearing material for either the bushes or the faced spindles used in planet wheel bearings. It is more than adequate for the loads which have to be carried. Planet wheel bearing pressures up to 750 lb per square inch have proved satisfactory but pressures are usually well below this figure. It is often unnecessary to supply oil under pressure for gears which are fitted with ball and roller bearings, splash lubrication being adequate.

Gearcases and Main Shaft Bearings.—The planet bearings alone are subjected to tooth reaction loads and therefore the main shaft bearings have only to support the weight of the components. This weight, the torque reaction from the gear and the thrust, when single helical gears are used, do not impose large forces on to the gearcase, and this can be of light construction.

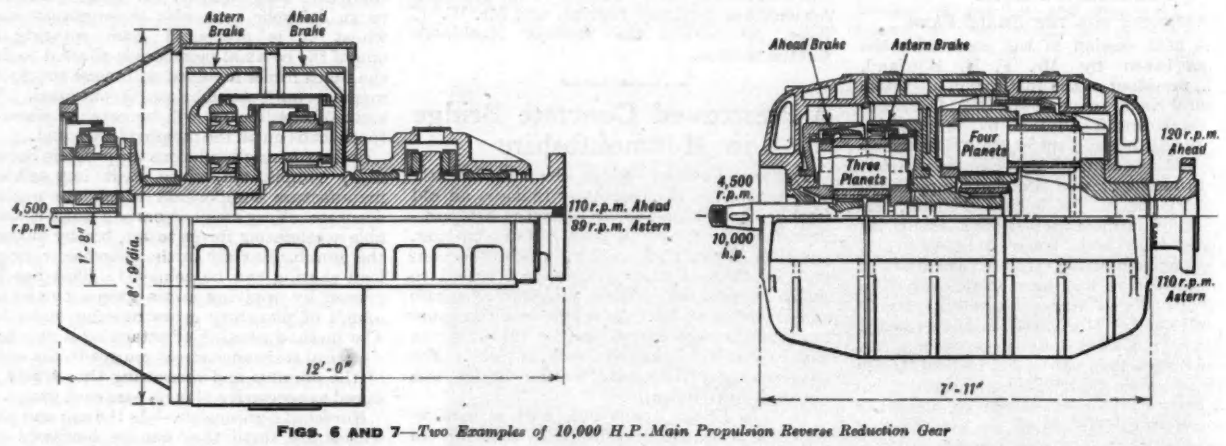
Planet Carriers. — Planet carriers should always be made as rigid as possible and the spacing of the holes for the planet wheel spindles must be of the highest possible degree of accuracy.

Lubrication.—A typical method of lubricating an epicyclic gear is shown in Fig. 1. The planet wheels are fed with oil led into the centre of the low speed shaft and thence by radial holes via the centre of the planet wheel spindles to the bearings. The sunwheel planet contacts are lubricated by oil, led into the centre of the sun wheel, which flows by radial holes into two tooth spaces. The planet-annulus contacts are lubricated by the oil mist present in the gearbox. The gear tooth type flexible coupling is lubricated by radial holes leading into each tooth space.

It is always desirable to use a filtered oil supply.

Gear Sizes.—Parallel shaft gear sizes are usually referred to in terms of the centre distance between the shafts, and in epicyclic gears it is easiest to refer to the gear size in terms of the annulus pitch circle diameter.

It is possible to cover all marine auxiliary and many main propulsion applications with gears, the largest of which would not have an annulus diameter of more than 25in.



FIGS. 6 AND 7—*Two Examples of 10,000 H.P. Main Propulsion Reverse Reduction Gear*

MANUFACTURE

General.—The load-carrying capacity, life and quietness of gears depend on experience in design and on accurate manufacture, both with regard to the gear tooth form and the general machining. Within a comparatively small range of gear sizes it is possible to cover all marine auxiliary and many main propulsion requirements.

All the component parts are light and easy to handle and the general machining and gear tooth forming can be carried out on a narrow range of machine tools which are cheaper and need less room than machine tool equipment for manufacturing parallel shaft gears of equivalent powers.

A high degree of accuracy in gear tooth formation is necessary. The general dimensional accuracy required for the other components is the same as for any modern precision piece of engineering ; but, in addition, it is important to achieve good positional accuracy. This is especially so for planet carriers and the bores of the bearings. Where large numbers are involved, these points are best covered by a substantial degree of jigging or by the provision of special-purpose machine tools, but where a small number only is involved requirements can be met by a production type of jig boring machine.

The final check that components have been made to the required standard is that they should run satisfactorily when they have been assembled without fitting, and in practice this can be achieved. Care in handling must not be overlooked as an essential item in the sequence of manufacture.

More damage can be done in initial test bed running than in the whole life of the gears if adequate precautions are not taken to clean out all oilways and if the interior surfaces of the gearbox are not free from dirt and swarf. Special care should be taken with the filtering of oil used during test running.

Hobbing and Planing with Special Reference to Internal Gears.—The hobbing process has been developed so that the pitch accuracy is of a very high order. But to cut an internal gear on a hobbing machine requires a cutter specially designed for the gear in question and any alterations in design necessitate an alteration to the form of the cutter. The reason for this is that, when cutting internal teeth, the hobbing machine is being used to carry out a continuous form milling operation and only one of the teeth on the cutter is complementary to the required gear tooth space.

Gear planing machines, using rack type cutters for external teeth and with provision for cutting internal gears with Fellows type cutters, have been successfully used for epicyclic gear components. The necessity of changing the cutter for each change in design does not arise when annuli are planed. The designer is restricted in his choice of helix angle by the lead of the guides provided for the machine and the diameter of the cutters. High-quality work can be produced by planing and it is generally the most suitable method for producing internal gears.

The annulus and coupling rings of the gears illustrated are slight in section and it might appear difficult to keep them in an undistorted condition, but it has been found possible when the correct technique is used. Grinding the bore and outside diameter is inadvisable and annealing after rough machining the blank rings is considered to be essential. The teeth in the rings are always cut in a free condition, i.e., care is taken not to distort the ring when clamping it to the planing machine table.

Shaving.—For batch production an economical method of producing hardened sun and planet wheels is to use nitriding steels, the gears being shaved, if considered necessary, before hardening. Once a cutter has been made the tooth profile cannot be altered without regrinding the cutter, which results in a reduction in its life.

Grinding.—Form grinding is more often used for large batch production and when changes in design are infrequent. Generating grinding is perhaps more suitable when small numbers of a varied range of designs are required.

Checking of Toothed Components.—It is advisable to use a universal gear checker to enable the helix angle, profile and concentricity to be recorded at one setting. This saves time and measurements are made from one basis. The comparative smallness of epicyclic gear parts enables the actual profile and helix to be easily measured with certainty and, by using planet carriers, made to fine dimensional

accuracy, the necessity of providing special meshing rigs does not arise.

Planet Carriers.—The spacing of the planet spindle bores in the planet carrier should be of the highest accuracy and they should be precision bored on a jig borer or special-purpose machine. Parallelism of the bores must also be kept within fine limits to enable the gears to be assembled without any hand work and to ensure consistent meshing of all the wheels.

Planet Wheel Bearings.—Spindles faced with white metal are no more difficult to produce than white metal lined bushes, and with such spindles the bores of the planet wheels may be honed and polished.

Table I gives the data for gears from which some of the advantages to be gained by the use of epicyclic gears are easily seen. These are summarised as follows:—Smaller dimensions, lower weight, higher efficiency, lower pitch line velocity, coaxial arrangement of driving and driven shafts.

Table I.—*Table of Comparisons Between Parallel Shaft and Epicyclic Gears*

	Turbo-alternator					Turbo-pump				
Duty*	2000kW					1180 h.p.				
Power	6000/1500					7000/690				
Speeds in r.p.m.	4 : 1					10·15 : 1				
Ratio	Parallel shaft side pinion		Epicyclic planetary			Parallel shaft side pinion		Epicyclic planetary		
Type of gear	6500		900			7300		1900		
Weight in lb	3400		400			4300		750		
Weight in lb. of largest component to be handled	Pinion	Wheel	Sun planet		Annulus	Pinion	Wheel	Sun planet		Annulus
Component	2¼–3¼ per cent nickel steel, 40–45 tons per sq in U.T.S.	Carbon steel, 31–35 tons per sq in U.T.S.	Alloy case hardening or nitriding steel, 65 tons per sq in minimum U.T.S.		Alloy or carbon steel 55–65 tons per sq in U.T.S.	2¼–3¼ per cent nickel steel, 40–45 tons per sq in U.T.S.	Carbon steel, 31–35 tons per sq. in U.T.S.	Alloy case hardening or nitriding steel, 65 tons per sq in minimum U.T.S.		Alloy or carbon steel 55–65 tons per sq in U.T.S.
Materials	175 to 205	135 to 151	630 after case hardening		250 to 295	175 to 205	135 to 151	630 after case hardening		250 to 295
Brinell number	80		250		85	85		450		49
$K=\frac{P}{d}\left(\frac{R+1}{R}\right)$ (see note below)	2×8		2×3·375			2×4·625		2×2·5		
Face width, in	0·589		0·452			0·465		0·452		
Circular pitch, in	8·44	33·54	5	5	15	5·02	50·98	1·97	8·01	18·0
Pitch circle diameter, in	221		98			153		55		
Relative pitch line velocity in ft per sec.	106		450			133		300		
Maximum bearing pressure in lb per sq in										
Losses in horsepower:										
Bearing	78		23			23		7		
Tooth	27		21			11		10		
Efficiency	96		98·2			97		98·5		

* In the table we have omitted, for brevity, three other examples of applications.

$K=\frac{P}{d}\left(\frac{R+1}{R}\right)$ for two external wheels in contact.

$K=\frac{P}{d}\left(\frac{R-1}{R}\right)$ for an external and internal wheel in contact.

Where P = load in lb per inch of face width
d = pitch circle diameter of smallest wheel in train
R = ratio of the speeds of the two wheels in contact

Future Trends

Reciprocating engines for larger powers have generally been operated at speeds which allow direct drive to the propeller shaft, but for smaller powers internal combustion engines run at speeds which demand the incorporation of gearing between the engine and propeller shaft. The unidirectional engine necessitates the use of a reversing mechanism and it is here that epicyclic gears offer a solution. Whilst epicyclic gears have been employed regularly for small craft, there has been a reluctance to use them for higher powers. The tendency to build oil engines developing up to 2000 h.p. at speeds well in excess of propeller speed will bring to the fore the use of reversing epicyclic gears.

The increasing use of high-speed, high-efficiency steam turbines and the continual development of gas turbines for main propulsion units demand an efficient and reliable form of reverse reduction gear. An epicyclic gear would assist greatly towards achieving the maximum possible efficiency in such installations. For example, in a steam turbine running at 4500 r.p.m. and developing 10,000 s.h.p. there is a constant loss, when going ahead, of some 200 h.p. due to astern turbine windage. A double reduction gear for this power would involve the loss of a further 300 h.p. A reverse reduction epicyclic gear could limit the total loss to about 200 h.p.

A gear suitable for 10,000 s.h.p., reducing from 4500 r.p.m. to 110 r.p.m. ahead and 6700 s.h.p. reducing from 4500 r.p.m. to 89 r.p.m. astern is illustrated in Fig. 6. In this arrangement both when going ahead and astern all the components are doing useful work. The gear comprises three epicyclic trains; one double helical reduction train followed by two spur trains, which incorporate the reversing features. The double helical planetary train gives the initial reduction ahead and astern and the output shaft of this train is connected to the sun wheel of the second train.

When going ahead the brake drum of the third train is held stationary, when the second train operates as a planetary unit and the third as a solar. When going astern the brake of the third train is released and that of the second train applied, causing the second train to operate as a star gear and the third as a planetary. The difference in rotation is obtained, therefore, by changing the character of the second train.

Designed on a very conservative rating, the total weight of this reverse reduction gear, including a hydraulic braking system and control equipment, Michell thrust block and gearcase, is estimated to be about 35 tons and the space required is approximately 12ft long by 9ft diameter.

A Pametrada proposal which was illustrated in T. W. F. Brown's paper (see references, p. 416) is reproduced in Fig. 7 by permission of the North-East Coast Institution of Engineers and Shipbuilders. This gear is also for 10,000 s.h.p., 4500 r.p.m. to 120 r.p.m. ahead and to 110 r.p.m. astern. The weight is estimated to be about 20 tons, including the hydraulic brakes but excluding the thrust block.

The reversing system which is incorporated in the first train comprises a driving sun wheel meshing with three compound planet wheels, the second parts of which mesh with another set of planet wheels mounted in the same planet carrier. These last wheels engage with the second of two annuli, each of which is connected to a brake drum. The planet carrier of this train is the driven member for both running conditions and drives the sun wheel of the final reduction train, which is a planetary gear with compound planets. When going ahead the ahead brake is applied, which makes the first part of the compound planet train a simple planetary system. The single planets and second annulus with its brake drum are allowed to idle, whilst the planet carrier drives the sun wheel of the second train, which in turn drives the planet carrier of the reduction train in the desired direction. For the astern condition the ahead brake is released and the astern brake applied. The second part of the compound planet train now operates as a planetary unit, the single planets acting as idler wheels to achieve the reverse rotation while the first part of the compound planets, the first annulus and its brake drum idle.

These examples are two of the many configurations of epicyclic gears which could be used to satisfy reverse reduction requirements for single or tandem turbines. The many mechanical problems in reversing gears of such powers would need considerable development, but there is every reason to believe that they could be solved.

Another manner in which the "in-line" property of epicyclic gears could be utilised is by installing the final stage of a propulsion gear as a self-contained epicyclic unit in the shaft tunnel adjacent to the stern gland. By this means the intermediate shafting could be run at a speed considerably higher than that of the propeller, thus allowing a reduction of intermediate shaft diameter and weight.

An attractive overall arrangement of pro-

pulsion machinery could be achieved by the combined use of epicyclic and parallel shaft gears. The epicyclic gear could be used either as a first or second reduction. It is often desirable to reduce the weight and space taken up by machinery and this can be assisted in many instances by the incorporation of epicyclic gears either as speed reducing or increasing units. Other applications include winches, forced or induced draught fans and blowers, refrigerating gas compressors, oil engine superchargers and turning gear for main engines. Consideration could also be given to a further standardisation of motor sizes and speeds with the help of compact speed increasing or reducing gears to meet the wide range of auxiliary speeds needed. This would result in a substantial saving in electrical spares.

Conclusion

Striking developments have taken place in all forms of gearing due to the scientific approach which has been made to the design and manufacturing techniques involved. The authors feel that too little attention has been given to the effects of applying these developments to the epicyclic forms of gearing and an attempt has been made to remedy this omission by bringing to the notice of marine engineers some of the possibilities of present-day and future epicyclic gears.

Successful experience shows that such gearing satisfies the marine engineer's first and foremost requirement of reliability. Its compactness offers great advantages by its adoption in a wider variety of applications for higher powers than have so far received consideration.

It is the conviction of the authors that with determined development large-powered reversing gears will in the future become very serious competitors to the much larger and heavier straight reduction parallel shaft gears which are now in general use for main propulsion.

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World Petroleum Congress.—The permanent council of the World Petroleum Congress at a recent meeting in Paris assigned the Fourth World Petroleum Congress to Italy and it will probably be held in Rome during the last week in May and the first in June, 1955.

Unattended High Power Radio Transmitter

We learn from the B.B.C. that the new high-power (150kW) Third Programme transmitter at Daventry, which came into service in April last year on 464m, has been working unattended since January 13th: it is the first high-power transmitter to be operated by remote control. The B.B.C. has been operating several low-power stations in this way for some time past, but the unattended operation of high-power equipment is a much more difficult matter, and its solution represents an important step towards easing the present-day shortage of skilled manpower. Normally, at least two engineers per shift would be needed to operate a high-power broadcasting transmitter, but, by effecting the remote control of the station from a point which must be staffed, the trained technical staff normally in local attendance can be released for duties elsewhere. The remote control system being used has been jointly developed by B.B.C. and by Marconi's Wireless Telegraph Company, Ltd., the manufacturers of the transmitter.

The new transmitter, which is capable of a full output of 200kW, is operated with a maximum power of 150kW, to conform with the Copenhagen Plan. It was originally designed by the manufacturer to be suitable for remote operation over long distances, and tests have proceeded while it has been in service—initially as a manned station. The transmitter is built as two identical units, the outputs of which are combined in a specially designed circuit so arranged that no transference of power takes place between the two sections; this circuit was designed and constructed by the company to B.B.C. specification. The task of applying the various power supplies to the transmitter is carried out automatically in the correct order and at the appropriate time intervals, by the action of a single "start" button at the remote control point. The operation of this "start" button, situated in the main building, brings on the air blowers for cooling the valves, followed by the valve filaments, and other supplies in their correct sequence, until, with the application of the main h.t. supply, both halves of the transmitter are working.

This sequence of events is initiated and controlled by a series of relays, a system of interlocks being incorporated to ensure that, not only are the supplies and services applied in the correct order, but any fault or failure of supply will arrest the progress of the operation. As each operation is completed a lamp on an indicator panel in the transmitter building is illuminated. On manual operation this serves to show the engineers how far the chain is completed. It also serves as a useful guide for locating faults when the station is on remote control; thus, if the transmitter shuts down and an engineer is sent to remedy the fault, he will look at the indicator panel and see that, for example, the auxiliary and main h.t. lamps are out. He will then check the auxiliary h.t. supply and associated circuits, since the indicator panel will show that the previous sections are in order.

When all the operations have been completed and the transmitter is on the air, indicator lamps at the remote points are illuminated. If these lamps fail to light within approximately two minutes of the operation of the "start" button, the engineer at the remote point knows that some fault has developed which needs investigation.

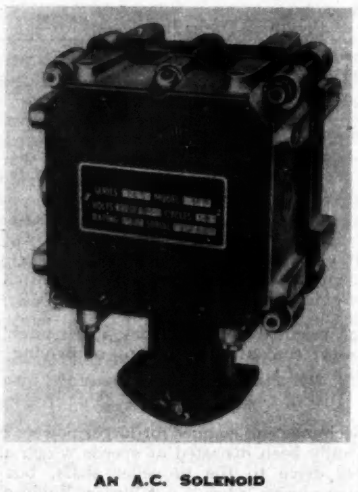
Two specially designed automatic monitors developed by the designs department of the B.B.C. are arranged so that one continuously monitors each half of the transmitter. In the event of the automatic monitor on either half "noticing" a programme fault it automatically shuts down that half of the transmitter with which it is associated. At the same time, to prevent a complete shut-down of the station as the result of a comparatively minor fault, the monitor on the faulty unit removes the shut-down control from its counterpart on the healthy section, substituting an alarm circuit. A third automatic monitor checks the transmission from the aerial. To prevent the service being interrupted through a failure of the monitor itself, an ingenious arrangement is incorporated which enables it, if a programme fault is suspected, to ensure that its own circuits are functioning correctly before shutting down the transmitter.

Since the monitor operates by comparing the programme as received with the programme as radiated, it is essential that a momentary shut down of the transmitter due, say, to the operation of the lightning protection gear, shall not be regarded as a programme fault. The automatic protection of the transmitter itself incorporates a number of devices which, on the occurrence of a fault, will remove the main h.t., wait a few seconds and then restore it. If the fault persists the main h.t. is again removed and restored. After the third attempt the transmitter automatically closes down and gives an alarm. During the three attempts to restore normal conditions the operation of the monitor is automatically suppressed. In the event of the breaks in programme being due to some other cause, however, the suppression would not take place and the monitor itself would close down the transmitter.

It is fitting that this important development should be made at Daventry, with its long history of pioneering work in broadcast engineering: for it was from Daventry over twenty-six years ago, that the first high-power, long-wave broadcasting transmitter in the world (5XX) went into service.

An A.C. Solenoid

Our illustration shows one of a range of four a.c. solenoids manufactured by Westool, Ltd., St. Helen's, Auckland, Co. Durham. The solenoid illustrated (model 1) produces a pull, while the other solenoids (models 2, 3 and 4) produce a thrust. For each solenoid there are five alternative ratings with different "on-off" ratios and producing forces of 10 lb, 20 lb, 30 lb, 40 lb and 50 lb respectively, over a range of about 0·5in to 1·75in stroke.



An A.C. Solenoid

When working against gravity the useful force is reduced by 2½ lb in the case of model 1 and 3¾ lb in the remaining models.

As shown in our illustration, the solenoid is assembled in an enclosed frame, with removable inspection cover and conduit entry for the wiring. Standard windings are available to suit eight single-phase voltage ranges from 190–210V to 500–550V at 50 c/s. The maximum stroke is 1¾in and the pole faces are accurately ground to reduce noise. Excluding the plunger itself the overall dimensions of the solenoid frame are 5½in wide, 5½in deep, and 4¾in from front to back, the total weight of model 1 being about 15 lb and of the others 16 lb. Four sets of four tapped holes $^{9}/_{32}$in diameter provide universal mounting.

Electronic Telephone Exchanges*

By T. H. FLOWERS, M.B.E., B.Sc., M.I.E.E.†

Introduction

A telephone exchange is primarily a switch, which is itself an aggregate of switches, for the interconnection of transmission circuits entering it. One feature common to all existing exchange systems is that the transmission circuits are terminated on switches including metal contacts which are mechanically closed as required through the agency of a control system. The mechanical movement is produced by electromagnetic attraction of an iron armature which operates through a link system or motor mechanism to bring the contacts together. The control systems are built up largely of the same kind of switches, although other switching devices, such as rectifiers and gas discharge tubes are being used increasingly.

Switches which rely for their action on mechanical movement of metal contacts are subject to wear of the mechanical parts, wear of the contacts if any appreciable sliding motion of one contact over another takes place, erosion of the contacts due to current passed through them, and particularly by current broken by them, and a degree of uncertainty in the electrical contacting due to surface films and dust collected from the atmosphere. Such exchanges thus need a certain amount of continuous maintenance and are subject to some degree of faulty operation. The art of designing automatic telephone exchange systems is largely that of minimising the defects enumerated without increasing the cost of the apparatus, and the achievements in this direction have been remarkable. It has been realised for a number of years, however, that there are switching devices, such as vacuum valves, gas discharge tubes and rectifiers—collectively referred to as electronic switches—which, having no mechanical movement or contacting surfaces exposed to the atmosphere, are free from difficulties due to these causes. They have their own peculiar difficulties, but engineers in many countries have naturally asked whether automatic exchanges can be constructed economically entirely of such devices and, if so, whether further progress towards increased reliability and reduced capital and maintenance costs of telephone exchanges is more likely to be achieved by such means than by further developments of electromagnetic switches. Recent work in Britain indicates that fully electronic systems which may possibly compete with electromagnetic systems in cost and reliability can be produced, but the economics and reliability of such systems have yet to be proved. Publication of other work in this and other countries is as yet limited to a few patents, a selection of which is given in the references. These disclosures do little more than suggest specific solutions to the general problem.

The paper describes the first steps which were taken in a research organisation confronted with the problems of determining what practical forms electronic exchanges might take, which of these forms was likely to be the most economical and reliable, and how this form might compete with existing electromagnetic systems. This approach is thought to be consistent with the present state of the art and preferable to describing any one particular system.

The problem of the form an electronic exchange might take is not adequately solved simply by the substitution of electronic switches for electro-mechanical ones in existing systems. An electromagnetic switch is a mechanism which closes metal contacts having characteristics which, in joining two circuits together, are quite different from those of an electronic device such as a valve or rectifier performing the same function. Moreover, the greater operating speed of electronic switches makes possible switching systems which are impracticable with slower-operating electromagnetic switches. The design of electronic exchanges should therefore be approached by way of basic principles rather than analogy with existing exchanges.

[The author then described various forms of connector switches and typical subscribers' line equipment and outlined the general principles of selection systems with examples of group and free circuit marking and of a post-setting-up control circuit.]

It is perhaps opportune here to define what is meant by an electronic exchange. Parts of existing electro-mechanical systems may be replaced by electronic devices and units, but this would not make them into electronic exchanges. On the other hand, exchanges which are otherwise completely electronic are very likely to have mechanical subscribers' meters and to be controlled by mechanical dials; they are not therefore completely electronic, but are certainly intended to be covered by the term "electronic." Any definition of the term is therefore bound to be arbitrary to some degree, and in this spirit it is suggested as a practical definition that an exchange is electronic if the connector switches are electronic.

The philosophy of the paper is that any automatic exchange can be divided into parts, namely, connector switches, selection system, register senders and register translator senders, and post-setting-up control units. This division is certainly applicable to existing systems. It might be thought possible to produce some electronic structure so novel as to invalidate analysis based on known systems, but no such possibility is known to the author.

Effect of Electronic Exchanges on Transmission Networks

A complete telephone system is a complicated network of transmission lines interconnected by the exchanges in innumerable combinations as demanded by the users of the system. The problems of connecting lines together by exchange switches with metal contacts having substantially no effect on the transmission are well understood. They include the effects of overall loss and the variation of overall loss of the lines with time, reflections due to mismatch of lines connected together, attenuation and non-linear distortion. The outcome is a practice of line construction and maintenance which provides a satisfactory standard of transmission at the minimum cost for the prevailing conditions. Electronic exchanges would make no difference to the fundamental problems or the principles of planning the system, but might compel or at least encourage changes in practice.

The transmission through electronic exchange switches introduces extra possibilities of overall loss and variation of overall loss, of reflections and distortions. To that extent the problem is made more difficult and its solution in consequence less satisfactory. There are, however, more than compensating advantages to be gained. Connector switches which include one-way amplifiers in their transmission paths must provide four-wire transmission through the switches; the amplifier gains will usually be such as to make the losses through the switches zero. There will, however, be a variation of the overall loss which has to be taken into account; but, in general, this will be more than offset by the greater gain which can be employed in line repeaters because of the four-wire switching. In addition, a subscriber's line connected to four-wire switches including amplifiers in the four-wire channels is presented with a termination at the exchange which does not vary with the connections made. Side-tone balance at the instruments may then be improved, with a corresponding improvement in transmission.

Network planning tends at present to avoid amplifiers in local junctions at the expense of copper in the transmission circuits. In electronic exchanges with amplifiers available as a matter of course the tendency should be reversed, with a resultant saving in the cost of junction plant. For those systems which provide four-wire switching in all exchanges the greater gain thus possible in the line amplifiers should result in still further savings in junction and particularly in exchange line plant. Finally, frequency division and time division exchange switches offer opportunities for carrying these types of transmission into local and short-junction networks as parts of an integrated transmission and switching system. It is not difficult to visualise, for example, the present unattended automatic exchanges being replaced by multiplex terminals connected by coaxial cable to a larger exchange in which is located all the switching for an area of considerable size. The paper can do no more than draw attention to the possibilities and emphasise that the economics of electronic exchanges is not merely the production of exchanges which cost no more than electro-mechanical exchanges.

Electronic Exchange Costs

There is little in the way of similar apparatus in production to give a guide to the capital cost of electronic exchange equipment in bulk production. However, from several points of view one might reasonably expect that equipment to be much less expensive than electro-mechanical equipment of any sort. The number of parts required is a mere fraction of that required by the Strowger system, which is as cheap as any other known electro-mechanical system. Mass production of the parts is thereby facilitated, and the costs of storage, handling and stock provision are greatly reduced. Tooling is greatly reduced, as is also the need for maintaining stocks of tools for obsolescent designs. New designs are quickly built up from the few standard parts, so that development costs should be small. It is, however, impossible to hazard a guess as to the ultimate cost, as it is almost certain that future work will bring simplification of circuit techniques and components.

Capital costs are recovered over the life of an exchange. The character of the exchange apparatus involved in the two cases suggests that electronic exchanges may have a longer economical life than electro-mechanical exchanges, resulting in a lower annual charge for any given initial expenditure.

No new system would be adopted for replacing existing systems unless the labour absorbed in running and maintaining the new exchanges was less than that of their present counterparts. In electronic exchanges there would be nothing corresponding to mechanical adjustments and very little to clean. Labour would thus be limited to fault finding and replacement of faulty parts, which should be largely limited to hot-cathode valves. The number of such valves in a 10,000-line exchange may eventually be as low as 20,000, and with this number failures would occur at an average rate of some fifty per day if they had an average life of one year each. The cost of replacement and the effect on service would in these circumstances be prohibitive. At least a five-year life is a necessity, and there is good reason to think that this and more can be achieved. It is too early for the author to assess the possible effects of transitor development on this and other questions. With a modern and largely automatic fault-finding system maintenance should be largely a matter of fault analysis by a small highly trained and centralised body of men, and fault clearing a matter of changing small units. For these reasons it is not expected that the labour required would be anything like as much as is expended in the present exchanges.

The power absorbed by electronic exchanges may be expected to be a constant load due to the continuous current drawn by hot-cathode valves, plus a smaller load proportional to the traffic carried. Hot-cathode valves should be most numerous in multiplex type exchanges, where each subscriber and junction line has one valve. At an estimated power of 3W per line 25kWh per annum is consumed for each line. The cost of this is only a small fraction of the total cost of telephone exchange service. A similar number of hot-cathode valves in the rest of a 10,000-line exchange would involve a total of about 60kW of continuous load plus an additional load proportional to the traffic. The importance of this expenditure of power is probably not so much its cost as how to lose it as heat. However, any estimate regarding power requirements of electronic exchanges may

* Abstract. Institution of Electrical Engineers, London, Thursday, March 13th.

† Post Office Research Station.

very possibly be invalidated by valve and other developments in the next few years. The ultimate requirements are regarded as indeterminate.

Service Given by an Electronic System

The term "service" includes facilities, transmission and reliability as experienced by the subscriber. So far as facilities are concerned, there is no reason to think that there is any fundamental difference between electronic and electro-mechanical switching. Any facility which can be provided by one kind of system could also be provided by the other. Any advantage which electronic switching might have in this respect would result from making a clean start with a new system.

The speed of operation of electronic switches should result in local calls being connected immediately the final digit is signalled by the subscriber. On the longest national call switched through exchanges, all of which were electronic, the delay following the signalling of the final digit would be mostly determined by the rate at which number information could be passed on from exchange to exchange, and might reach three seconds. The quicker connection times can be regarded as a service improvement, although modern designs of electro-mechanical systems could achieve nearly as much.

If transmission is measured in terms of linearity and variation of gain through the switches, mechanical contacts, so long as they make good contact, are always better for transmission purposes than electronic switches. In electronic exchanges which provide four-wire transmission, even in the local exchanges better overall transmission can be given than is provided by the existing system, despite the variation of loss through the exchanges. Connections made through existing types of exchange are occasionally subject to noise which causes a good deal of annoyance to subscribers. The cause of the noise is most often unsoldered joints, either intentional—e.g., wiper and bank contacts and relay contacts—or unintentional—i.e., dry joints. In electronic exchanges there need be no intentionally unsoldered joints; plugs and jacks should be avoided, except perhaps for power connections where they are not likely to do any harm; valves should also be soldered in to avoid the troublesome pin-and-holder unsoldered joint. The problem of dry joints is being successfully solved. Noisy connections through electronic exchanges should thus be rare, but electronic exchanges may have as yet unsuspected or so far unexperienced sources of noise. Poor insulation between heater and cathode of a valve could produce an unpleasant level of noise without giving a detectable fault. Hence, only experience can finally decide the question.

At present reliability is perhaps the most controversial aspect of the subject of electronic exchanges. Whether this type of exchange can be made inherently more reliable than the best electro-mechanical exchanges is a question which only time will determine with certainty, but there are reasons for thinking that it will be so.

All systems are designed and manufactured to limits which if satisfied will guarantee reliable service. Defective service is largely related to the opportunities for the apparatus not to be within design limits and the extent to which inspection and test can discover the defects. With electronic apparatus each component, once made, is thereafter incapable of being adjusted. The number and character of the components are such that every one can be measured for its essential characteristics as precisely as may be required. These characteristics are electrical quantities directly related to the performance of the part in the system, and they are not affected by assembly, wiring, shipping and installation on site. With electro-mechanical equipment the conditions are not so favourable. The characteristics of mechanical parts cannot be so accurately specified or measured in terms of performance in the system as those of electronic apparatus. The parts are so numerous that sampling is more often used than the testing of every individual item. Many hand adjustments have to be made, the quality of which depends on the skill of the adjuster and the vigilance of the man who makes the subsequent inspection. There remains the application of functional and other tests to detect faulty apparatus, but the efficiency of such tests is limited. The relay spring which has too little lift to ensure good contact is not readily detected by any externally applied test. Similarly, the pivot or hinge which is too tight or too loose is not easily detected until it gives trouble; what is worse, it may interfere with the proper functioning of the equipment for a long time until the trouble becomes apparent enough for detection. It is not suggested that electro-mechanical exchanges cannot be manufactured and maintained to give good service, but it is suggested that those conditions which can account for the small proportion of defective calls which occur on such systems may be largely absent in electronic exchanges. It may prove that electronic apparatus has peculiar sources of unreliability. What are sometimes referred to as catastrophic failures, e.g., valve heater disconnections in electronic apparatus and loose and broken parts in mechanical apparatus, are at present more likely in electronic than in electro-mechanical apparatus, and the deterioration of rectifiers and other electronic apparatus over periods as long as thirty or forty years is still to some extent an unknown quantity. Experience will show where the weaknesses lie, but at this early stage there is every reason to think that they can eventually be overcome.

Conclusion

It is hoped that sufficient outline has been given of some possible forms of electronic automatic telephone exchange to convince engineers that it is only a matter of time before such exchanges will be produced in a form suitable for service in any size of network. Whether electronic exchanges will have, relative to the best electro-mechanical exchanges which can be produced, some or all of the attributes of greater reliability and less capital and maintenance costs is not so certain, but there is encouraging enough evidence in these directions to justify proceeding with the development of such exchanges. The consequential possibilities in transmission network design and construction are such as to justify electronic exchange development even if the other signs were not so propitious.

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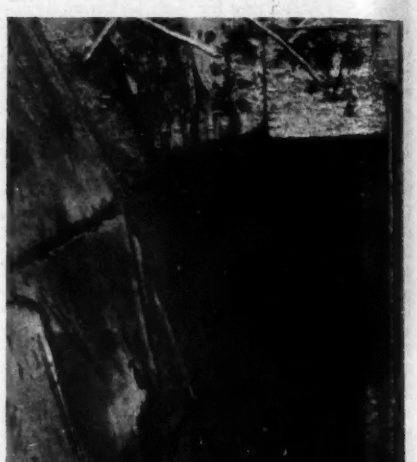
Refinery Progress.—A new catalytic process, for the removal of sulphur from oil during refining, has been developed by the Anglo-Iranian Oil Company. Known as "Autofining," the desulphurisation process operates at low pressure and catalyst regenerations are infrequent while hydrogen manufacturing facilities are not required. At the Llandarcy refinery of the company a unit producing high-grade kerosene is now electronically controlled, the instruments being used for the control of flow, pressure and level.

A Fish-Indicating Echo Sounder

The photographs reproduced herewith show the "Fischlupe," which is an echo sounder designed to indicate the presence of shoals of fish. This instrument has been developed by a German firm, Electroacoustic G.m.b.H., and sole rights for the United Kingdom and Commonwealth countries have been acquired by the Marconi International Marine Communication Company, Ltd.

The "Fischlupe" (literally, "fish lens") employs the same basic principle as the "Echometer," which sends out sound signals, receives the reflected pulses from the sea bed or from intervening fish shoals, and measures the time interval between the outgoing signals and their "echo." But, whereas previous instruments presented their soundings in the form of a paper record or a light flash against



Fitting of "Fischlupe" Transmitter Unit

a graduated scale, the information produced by the "Fischlupe" is displayed on a cathode-ray tube, as in radar.

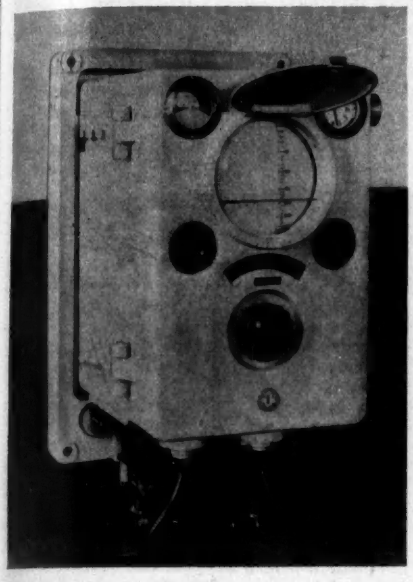
The "Fischlupe" has a maximum indicating depth of 300 fathoms, and employs two oscillators, one for transmission and one for reception of the transmitted high-frequency sound pulses. The oscillators are small and are fitted flush with the shell plating, as shown in our first illustration. Besides the indicator, which is shown in the second illustration, the equipment consists of a rotary converter, a pulse generator unit, and a control unit.

The operation of the equipment is simple. The main lift control is set to "survey" position and the equipment switched on. The face of the cathode-ray tube then shows a vertical line of light representing the full range of 300 fathoms, with horizontal deflections occurring at the depths representing the sea bed and any intervening fish which may be present. Adjustment of the sensitivity control clarifies these deflections. The main lift control is then rotated clockwise until the top of the horizontal deflection indicating the sea bed is brought into line with a horizontal red mark on the tube face. When this is done the reading on the scale shows the true depth.

If fish are observed, the lift control knob is again turned clockwise, when the instrument becomes focused upon a 45ft vertical section of the sounding. The diameter of the tube face now represents 45ft instead of 300 fathoms

as in the "survey" position, and fish indications which previously occupied only a small portion of the vertical line are distributed over the whole length of the line.

As the lift control is rotated further, the luminous echoes on the screen move upwards, almost giving the impression that the observer is in a diving bell, scanning the water through which he is descending. When the shoal indication is in position on the face of the tube,



THE "FISCHLUPE" FISH INDICATOR

the depth, accurate to within about a foot, can be read from the scale under the sector-shaped window below the screen, and if the shoal should rise or descend, its movements can be followed by adjustment of the lift control.

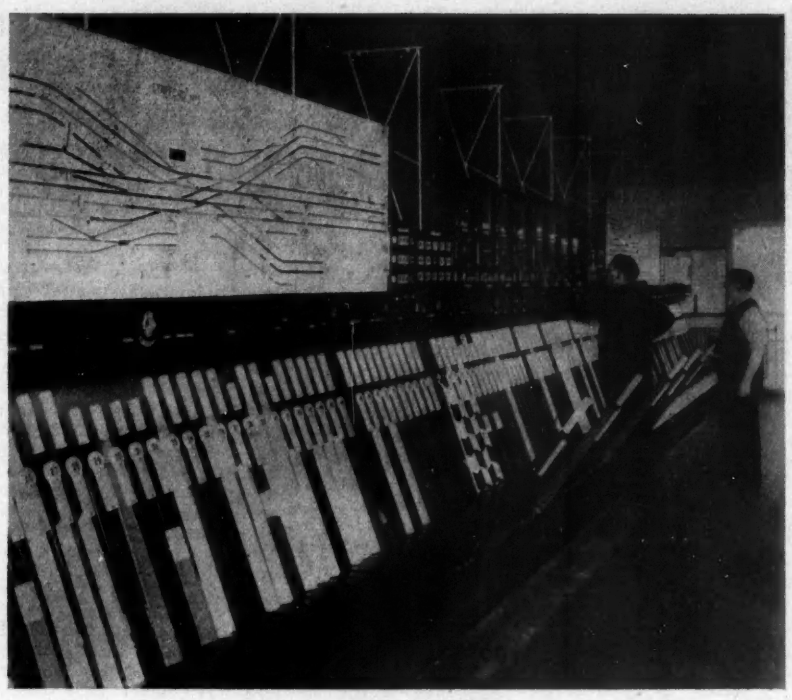
Although the "Fischlupe" can also be used for normal echo sounding, its principal function is fish indicating, and it is best installed as a complementary instrument to the Marconi marine "Seagraph" or "Seavisa." Fitted in a suitable position in the wheelhouse, the "Seagraph" and "Fischlupe" between them provide permanent indication of soundings and a "close-up" of fish indications—a useful combination for fishing vessels of all classes.

New Signalbox at Stafford

We have received from the London Midland Region of British Railways particulars of the new "No. 5 signalbox" which is shortly to be put into service at Stafford on the main line between Euston and Crewe. This box has been built opposite the existing box and it will control the up and down fast and slow lines at the north end of the station, and the junctions between these lines and those to Wellington and Stafford Common. Stafford is an important junction, as at the south end of the station the direct rail connection between the Birmingham area and the north joins the main line.

One of the reasons for building the new box is that the lever frame of 123 levers in the existing signalbox has become uneconomical to maintain, and it could not have been altered to operate the remodelled permanent way layout, which had been designed to give better operational facilities, and is being laid in flat bottom rail. The operating floor of the existing signalbox is set some 23ft above rail level, largely to give the signalman a view of the line on the north side of the signalbox over an adjoining overbridge. With this arrangement, however, the signalman cannot readily see trains passing the signalbox during bad visibility. Although the operating floor of the new signalbox is only 12ft 6in above ground level, the installation of track circuits and the latest electrical controls will more than compensate for any loss of visibility during clear weather.

Colour light running signals have been installed on the main lines in the area to be controlled by the new signalbox, and they form the first part of a complete multiple aspect colour light signalling system which will improve traffic working through Stafford generally.



LEVER FRAME IN STAFFORD NO. 5 SIGNALBOX

The new mechanical lever frame, which has already been installed in the new signalbox, is shown in the illustration reproduced above. It has 150 levers, and is of the normal L.M.R. pattern with catch handle locking, and is arranged for mounting directly on the operating floor, with the counter-balance arrangements and electric lever locks below. All the points, &c., will be mechanically operated, as will the ground signals provided for shunting purposes.

Single arm ground signals are used throughout the system, with stencil letter indicators where it is necessary to give an indication of the route which has been set up. Two such signals, one in the up fast and one in the up slow line opposite the new signalbox, will be passed in the facing direction by all trains. These signals precede the relevant colour light running signals which have been positioned further away, in order to maintain a reasonable signal to signal distance.

The colour light running signals are provided with junction indicators and position light subsidiary signals as required, except on the down slow line and the down platform line, which connects with the down fast line. Theatre route indicators have been installed here, as the speed of trains is limited. The junction indicators will also display the route for the subsidiary signal, and this is the first London Midland scheme which has been so arranged. Previously stencil letter indicators were provided specially for this purpose in addition to the junction indicators. Owing to the limited number of routes concerned, no selection has been employed for the running signals and separate levers have been used for each route.

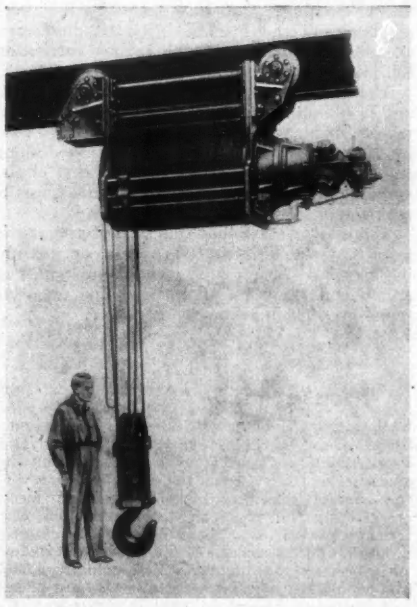
Duplicate illuminated diagrams are carried on the block shelf, which will have the signal repeaters mounted on the face, immediately over the lever concerned. All the other train signalling instruments will be mounted on this block shelf, but the usual block telegraph needles will be replaced by red and green lamps for "Train on line" and "Line clear" respectively.

The lever frame is mounted in the new signalbox on the side away from the running lines, so that the signalmen will have a clear view through the wide windows, and the concrete roof is extended to form a canopy which protects the windows from glare and driving rain.

A 10-Ton Capacity Pneumatic Hoist

We have received from the Globe Pneumatic Engineering Company, Ltd., of 58, Victoria Street, S.W.1, particulars of a pneumatic motor hoist of 10 tons capacity, built at its Chadwell Heath works for installation by Foster Wheeler, Ltd., at the Shell Refinery at Stanlow. This unit, thought to be the largest air-operated hoist of its kind made in this country, operates on compressed air at 80/100 lb per square inch, and has a lift height of 60ft. When operating on air at 100 lb per square inch its consumption is about 200 cubic feet of free air per minute. Its design is such that its mechanism is in no way damaged should it be stalled due to accidental overloading or similar misuse.

We reproduce a photograph of the hoist together with a drawing which shows the arrangement of its mechanism. Power is supplied by a four-cylinder, 5 h.p., radial pneumatic motor, to which the air supply is

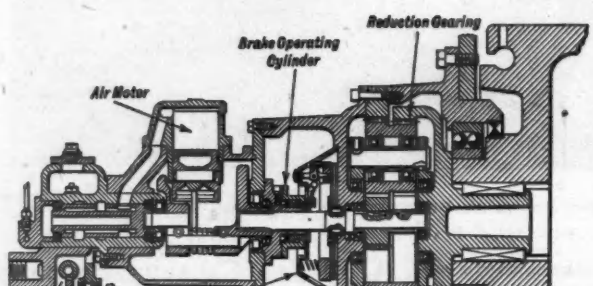


10-TON PNEUMATIC MOTOR HOIST

controlled by a sensitive poppet valve. This valve is operated through hand chains from floor level and it automatically centres to the neutral position when the control chains are released. From the air motor drive is transmitted to a grooved rope drum through compound double epicyclic reduction gearing having a ratio of 200 to 1 and running in a totally enclosed oil bath.

An air-operated brake fitted to the hoist is designed to hold the load in any position regardless of the air supply. This brake is based upon a 7½in diameter Borg and Beck clutch, the plate of which is keyed to the engine shaft. The brake is operated by a built-in, single-acting air cylinder which is released by air pressure immediately the main throttle valve of the hoist is operated by the control chains. During tests on the hoist the brake arrested and held the 15-ton test load when it was being lowered at full speed.

A 26in diameter grooved rope drum of high-duty cast iron is mounted on self-aligning ball bearings fitted with spring-loaded oil seals.



PNEUMATIC HOIST MECHANISM

The main frame of the hoist and the sheave are of fabricated mild steel. A bronze guide shoe which leads the rope on to the drum actuates through a link a limit switch which cuts out the air valve at the extreme lifting position. This link from the guide shoe rod limit switch to the control valve can be clearly seen in our illustrations.

The steel-framed lift block of the hoist carries the lower hook on a heavy-duty thrust race which enables easy positioning of a load during slinging. Loads are raised on four falls of rope and the machine grooved dual rope sheaves fitted in the lower block are carried on self-aligning ball bearings.

The complete hoist unit weighs some 2¼ tons and it is mounted on two pairs of roller bearing wheels, and at the refinery is carried on a 24in by 7½in rolled steel joist. It is traversed along this joist by means of an endless hand chain, through double reduction gearing fitted to the rear pair of trolley wheels.

The makers state that this type of pneumatic hoist and others of smaller capacity are becoming standard lifting equipment in oil refineries and chemical works where rigid and sensitive flameproof machines are necessary.

PHYSICAL PROPERTIES OF THE NICKEL IRON ALLOYS.—The Mond Nickel Company, Ltd., Sunderland House, Curzon Street, London, W.1, has published a useful booklet entitled "The Physical Properties of the Nickel Iron Alloys." It opens with a chapter on the history of the alloys and deals with the constitution of the nickel-iron system, mechanical properties, resistance to corrosion and electrical characteristics. There follow chapters on the properties of the binary alloys and of ternary alloys with special expansion properties—including nickel-iron-cobalt alloys, glass-to-metal seals, and nickel-iron-chromium alloys. A final section covers the constant modulus alloys, such as "Elinvar" and the "Ni-span" alloys.

South African Engineering News

(By our South African Correspondent)

Railway Progress During 1950–51

The report of the General Manager of the South African Railways for the year ended March 31, 1951, has been published, and, as in the past few years, again gives an account of traffic conveyed in unprecedented quantities and the establishing of more records. The report states that in order to cope with the exceptional growth of traffic, major improvement schemes, involving an expenditure of approximately £66,000,000, have been authorised during the post-war period, and that about £27,000,000 has already been spent. Approximately £11,500,000 has, in addition, been spent on the acquisition of 462 new steam and electric engines, and about £7,000,000 and £28,500,000 on 606 new passenger and 23,799 new goods vehicles, respectively. Since 1939–40, the number of standard gauge trucks employed on merchandise-carrying services has been increased from 47,546 to 72,281, or by 52 per cent. The tariffs of the South African Railways, it is emphasised, were amongst the lowest in the world before the war, and have not been increased to the same extent as has been the case in other countries. The rates on goods traffic are now 41·9 per cent higher than those obtaining in 1939; by way of comparison, it is revealed that the goods rates in America, on the Canadian National Railways, and in Great Britain, have advanced by 60 per cent, 45·2 per cent and 81 per cent respectively.

The report gives a brief review of the more important new works and improvements on open lines authorised during the year. During 1950–51, altogether £11,535,970 was expended on such works, compared with £12,864,586 during 1949–50.

Amongst the more important works authorised is Johannesburg's new passenger station. The first portion of this station, now in course of erection, was officially opened on September 13th last. It is the fourth station to be erected on the same site to cater for the constantly expanding railway travel requirements of the city. In 1890, "Park" halt was established, followed by "Park" station in 1894 (completed in 1897), and the present station building which was commenced in 1926, and completed in 1932.

The final step in the establishment of the new goods depot at Prospect to serve Johannesburg was completed in June, 1951, when the last remaining facilities of the old goods depot at Kazerne were transferred to the new depot.

Electric working over the sections Randfontein–Welverdiend and Midway–Bank was officially introduced in August, 1951, when the Minister of Transport took over the controls of a special train from Johannesburg and drove it into Welverdiend station. The opening of these sections of line will enable traffic to be hauled under electric traction from Pretoria, as well as from Springs and Welgedacht, to Welverdiend. It is significant that the electrification of these sections is the first major electrification project to be embarked upon in this country on sections equipped with steel sleepers, but, with the adoption of certain anti-electrolysis measures, no difficulties are anticipated. The sections will, in fact, serve as a test area in future experiments connected with the use of steel sleepers in electrical working.

The Grootvlei–Redan line, which was formally opened in July, 1951, is 39 miles 44 chains in length, and, estimated to cost £1,790,802, was built mainly for the conveyance of coal from the Springfield colliery at Grootvlei to the Klip power station at Redan. The colliery has been estimated to have a life of 47 years, and is capable of supplying some 2,250,000 tons of coal per year to the power station.

New records were achieved in the volume of traffic conveyed, the year being characterised by the complete absence of the "valley" periods, at one time a regular feature of railway operation in South Africa. Almost all classes of traffic contributed to the attainment of these results, but the factors that were probably of greater influence than any others, were the rapid expansion of mining, industrial, manufacturing and building activities, which had a direct bearing on such traffic as coal, and other base minerals, ore, cement and other building materials, machinery, merchandise, petrol, fuel oil, &c. The total volume of all classes of traffic conveyed reached the new record figure of 62,133,709 tons, representing an increase of 3,462,025 tons over the previous year.

Revenue from goods traffic (excluding coal) amounted to £57,678,193, being £9,262,025 more than the preceding year.

As in past years, agricultural products, minerals and ores, and building and fencing materials were again the most important commodities conveyed.

Steel Production

The new works of the South African Iron and Steel Industrial Corporation at Vanderbijl Park, supplementing the works at Pretoria, are now coming into production. By the turn of the year, according to the chairman of Iscor, ingot production, which, last year was 694,000 tons, is expected to reach 1,200,000 tons per annum. Counting local production and imports, South Africa's consumption of finished steel last year amounted to 1,086,000 tons. If expectations are realised, local production (last year 642,000 tons) of finished steel, will reach a rate of 1,050,000 tons per annum by the turn of the year. This indicates a remarkable development both of South Africa's steel demands and of productive efficiency.

Iscor's basic prices are considerably lower than the landed prices of imported steel on the Witwatersrand—the main market—the difference ranging from £16 to £76 per ton in favour of Iscor products. It is calculated that, in this way, Iscor is saving the Union about £18,000,000 per year, compared with the cost of imported steel, and the total saving in foreign exchange is put as high as £44,000,000.

Iscor's manufacturing and trading profit rose by no less than £470,156 last year to £2,389,055, and the net profit was £1,868,715. The entire capital is now held by the Union Government.

Hunyani Bridge

Some 20 miles to the west of Salisbury, the Hunyani River has, up to now, been spanned by a railway bridge which, on at least one occasion, was almost completely submerged during floods. Railway engineers have recently been engaged in erecting a new bridge further downstream from the old bridge. Between these two points, engineers employed by the Salisbury City Council, have built the new Hunyani Poort Dam, the waters of which will serve the city of Salisbury for many years to come. The new railway bridge was opened to traffic last year, and work was begun immediately on the dismantling of the old bridge and the recovery of track, as the bridge piers and railway earthworks will shortly be under water when the new reservoir is filled.

The new bridge and diversion have cost more than £210,000. Of this amount, about £60,000 was expended on the bridge, comprising £49,000 on concrete work and nearly £11,000 on steelwork.

The execution of the scheme presented some difficulty, because two cuttings on the diversion —each 1300ft long and 30ft deep—had to be blasted through rock. The excavation of 61,000 cubic yards of rock and 170,000 cubic yards of earth was also necessary.

Industrial and Labour Notes

Human Relations in Industry

This week there has been held in London, a conference arranged by the Ministry of Labour to discuss various factors affecting human relations in industry. Approximately 400 people have been taking part, including representatives of the British Employers' Confederation, the Trades Union Congress, the nationalised industries, the British Institute of Management, the Industrial Welfare Society and the British Association for Commercial and Industrial Education.

The conference was opened on Tuesday morning by the Minister of Labour, Sir Walter Monckton, Q.C., and the first day was devoted to the general consideration of papers dealing with the opportunity to work, the capacity of workers, the wastage of manpower, the will to work, and projects sponsored by the Schuster panel on the human factors in industry. There was also a paper entitled "Some Conclusions about Human Relations in Industry drawn from the Reports of the Anglo-American Productivity Teams," on which the principal speakers were Sir Cuthbert Clegg, president of the British Employers' Confederation, and Mr. T. Williamson, a member of the general council of the Trades Union Congress. The paper itself summarised those parts of the published productivity teams reports which relate in particular to the human factor in industry. In the paper it was pointed out that consultation existed almost throughout the American factory world, and operated at all levels from top management to the lowest grade. Such consultation in the U.S.A., however, was not formalised or regularised by the establishment of such joint organisations of representatives of managements and workers as were becoming more and more common in British industry. To American managements and workers, consultation was a matter of daily practice in the normal routine of the shop. The paper went on to say that none of the productivity teams considered that that approach to consultation was less sound or effective than the British approach, bearing in mind the industrial organisation and policy on both management and labour sides of American industry. To that must be added the general recognition in America that it was management's job to manage, coupled with the pervading belief that if employees participated in making a decision, they would carry it out. The paper on "Factors Affecting the Opportunity to Work"—the discussion on which was opened by Mr. John Marsh, of the Industrial Welfare Society—made special reference to the employment of older men and women, and that on "Factors Affecting the Capacity of Workers" covered such matters as selection, the training of young and adult workers, and the training of supervisors. The paper on "Factors Affecting the Will to Work" reviewed the state of joint consultation in this country's industries and discussed such subjects as communications in industry, and incentives.

On Wednesday, the conference divided into four groups for more detailed discussion of the matters presented in the papers. Yesterday, the final day of the conference, was devoted to the consideration of the reports from those groups.

Coal Production

Last week coal production in Great Britain amounted to 4,631,400 tons, which was about 60,000 tons less than in the corresponding week of 1951. The amount was made up of 4,393,400 tons from the deep mines and 238,000 tons from opencast workings. In the first eleven weeks of this year, coal output in this country totalled 49,253,700 tons, compared with 48,828,600 tons in the corresponding period of last year. Coal imports during that time were 309,100 tons, against 639,000 tons in the comparable weeks of 1951.

The latest report from the Ministry of Fuel and Power on the coal situation shows that colliery manpower continues to rise. In the week ended March 8th, there were 709,500 wage earners on colliery books, of whom 289,200 were face workers. A year ago manpower totalled 701,400. The shifts worked per wage earner in the week ended March 8th, however, were 5·07, against 5·11 a year earlier, and in the same week, the figure for total absenteeism was correspondingly higher. Total inland consumption of coal in the week ended March 8th was 4,339,000 tons—which again was less than in the comparable week of 1951—and exports and bunkers took up 277,000 tons. At the end of the same week, distributed coal stocks totalled 13,177,000 tons, compared with 9,738,000 tons a year earlier.

Employment and Unemployment

A report on the employment situation in Great Britain, which was issued by the Ministry of Labour at the end of last week, states that during January the total working population increased by 28,000 (all men) and at the end of the month was 23,454,000 (16,035,000 men and 7,419,000 women). Those serving in the Forces numbered 859,000, and the number of people in civil employment at the end of January was 22,203,000 (14,972,000 men and 7,231,000 women), which was 18,000 fewer than at the end of December.

During January there was an overall increase of 3000 in the number of people at work in the country's basic industries, bringing the total to 4,077,000. The biggest addition in this group of industries was in coal-mining, which added 7000 to its labour force during January. By the end of the month the number of wage earners on colliery books was 705,000, compared with 689,000 at the end of December, 1950. The total labour forces of the manufacturing industries declined by 2000 in January, making the number 8,784,000. Of that number, 2,596,000 were employed in the industrial group now classified as "engineering, metal goods and precision instruments," to the labour force of which there was an addition of 10,000 during January. In building and contracting 1,409,000 were employed, which was 13,000 less than at the end of last year, and in "professional, financial and miscellaneous services" there were 3,927,000 people engaged, or 6000 more than at the end of December.

Unemployment figures published by the Ministry of Labour show that on February 11th 393,480 people were registered as out of work, which was 14,739 more than on January 14th. The February figure included 216,850 men, of whom 24,518 were described as temporarily stopped. The Ministry estimates that the number of persons registered as unemployed on February 11th represented 1·9 per cent of the total number of employees. It also makes the comment that, in the week ended January 26th, about 216,000 operatives in the manufacturing industries were reported to be on short time, losing thirteen hours each on the average; on the other hand, in the same week, 1,158,000 were reported to be working, on an average, 7½ hours' overtime.

A Ports Efficiency Committee

The Secretary of State for the Co-ordination of Transport, Fuel and Power, Lord Leathers, announced last week that invitations to serve on the Ports Efficiency Committee had been accepted by Lord Llewellin, who will act as chairman; Sir Ernest Murrant, chairman of Furness, Withy and Co., Ltd.; Mr. F. A. Pope, a member of the British Transport Commission; Sir Douglas Ritchie, vice-chairman of the Port of London Authority; Major Roland Thornton, deputy chairman of the Mersey Docks and Harbour Board; and Mr. Tom Yates, general secretary of the National Union of Seamen. The secretary of the committee is Mr. S. R. Walton, Ministry of Transport, Berkeley Square House, London, W.1.

This committee has been charged with the task of speeding the flow of traffic through United Kingdom ports. Its terms of reference were announced on March 11th as being "to investigate the working of the ports of the United Kingdom, in particular the ports of London and Liverpool, and to secure the co-operation of all the interests concerned, including shipping and inland transport authorities, in securing a quicker flow through the ports of inward and outward cargo."

Trade Unions and Management

At a recent meeting of the Merseyside centre of the Institute of Industrial Administration, an address entitled "Trade Unions and Management" was given by Sir Vincent Tewson, general secretary of the Trades Union Congress. In the course of it he said that the T.U.C. had a double purpose in encouraging the study of management questions. It was to enable the unions to make more effective their contribution in increasing productivity and efficiency in industry, and also to develop the competence of union representatives in joint negotiations and consultations that were now the established procedure of the trade union movement.

Nationalised industries, Sir Vincent continued, called upon the unions to make their contribution in the field of industrial administration and management. At first, he remarked, the trade union movement had been ill-prepared to find a sufficient number of qualified and competent trade unionists for service, not only on the governing boards of the publicly-owned industries, but also on the joint production and advisory committees at lower levels. The educational services of the unions had then been more concerned about training for management of the unions themselves! But, Sir Vincent added, early last year the T.U.C. felt it essential to organise training courses in production and management, and those courses were now a regular feature of T.U.C. educational activity.

Sir Vincent went on to say that the T.U.C. interest in management and supervision was a realistic and practical concern with the organisation of industry in relation to modern needs. The T.U.C. took the view that there was a common interest in the improvement of industrial techniques on both the productive and managerial sides, and that that interest transcended the traditional out-dated attitude between employers and workpeople.

Lead Sales and Prices

The Secretary for Overseas Trade, Mr. Hopkinson, has stated in a parliamentary reply that the Ministry of Materials has now sold to the American Government 23,000 long tons of lead which was under contract from Australian, Mexican and Peruvian production. In each case the prior agreement of the producers had been obtained. The lead was for delivery during the next five months and had been sold at the United States internal price. Mr. Hopkinson added that this transaction, and the previous sale of 30,000 tons, would together realise about 22,000,000 dollars.

On Tuesday last, the Ministry of Materials announced that the price of lead to United Kingdom consumers had been reduced by £7 a ton to £163. This is the third reduction in price since the middle of last year, when lead reached its peak at £180 a ton. The Ministry also stated that all restrictions had been removed on the amount of lead which may be purchased for consumption. This latest price reduction has been made possible by lower prices which have been arranged with Commonwealth producers.

Notes and Memoranda

Air and Water

SWEDISH WIND TUNNEL.—A simple and inexpensive high-speed wind tunnel has now been completed for the Swedish Air Force at the Saab Aircraft Company, Linköping, Sweden. Power is derived from four de Havilland "Goblin" turbo-jet engines placed at the ejector end, their air mass flow being drawn through the test section via a large intake funnel at the other side of the plant. To avoid condensation in the test section, the fresh air can be heated by the exhaust gas, part of which is led back into the intake funnel.

A RADIO-CONTROLLED TARGET.—Some further details of a radio-controlled, high-speed target aircraft have been released by the Australian Government. This aircraft was designed and developed by the Government Aircraft Factories of the Australian Department of Defence Production at Melbourne to meet a British Ministry of Supply specification. A piloted version of this aircraft is at present being used to establish a satisfactory radio-control technique. The wing span of this version is less than 20ft and the length of the fuselage 22ft. In this relatively small area, provision has been made for the pilot, the flying controls and instruments, the "Adder" turbo-jet engine (made in this country by the Armstrong Siddeley Motors Company), with its twin lateral air intakes and jet pipe passing through the centre of the fuselage, the fuel tanks to give the range stipulated by the specification, normal airframe equipment and the radio. In the target version a retractable control skid has been fitted to cope with the abnormal landing velocity, during the preliminary testing period at least, before radio-controlled landing technique has been perfected. The target will take off on a tricycle undercarriage which, after jettisoning, is automatically braked. An expendable version of the "Adder" has been developed using materials which need only provide a life of a few hours.

Miscellanea

LLANDARCY OIL REFINERY.—Bench "B" distillation unit, which formed the first stage of the refinery expansion scheme, has processed more than 5,000,000 tons of crude oil since it was completed in October, 1949. Designed to process 1,500,000 gallons of crude oil per day, the unit, by careful control, has operated at a throughput of 2,000,000 gallons per day for long periods.

BULK BITUMEN AT DAKAR.—On March 15th, the first bulk bitumen facilities came into service at Dakar, Senegal, when the tanker "Mexphalte" pumped 2400 tons of hot bitumen ashore to a large heated storage tank newly installed on the quay. The bitumen will be carried by the Shell fleet of special bitumen tankers.

CONFERENCE ON BUILDING MATERIALS.—A conference on the application of the research reviewed at the Building Research Congress, 1951 (organised by the road and building materials group of the Society of Chemical Industry), with particular reference to papers presented to Division 2 of the Congress, is to be held on April 17th at the Institution of Structural Engineers. Those wishing to take part are invited to advise the General Secretary of the Society of Chemical Industry, 56, Victoria Street, London, S.W.1.

NATIONAL RADIO SHOW.—The Radio Industry Council states that the 19th National Radio Show will be held at Earls Court, London, from Tuesday, August 26th, to Saturday, September 6th. There will be restricted admission on August 26th, and the official opening will be on the 27th. The Northern Radio Show, City Hall, Manchester, is to be opened at 12 noon on Wednesday, April 23rd. The Radio Component Show will be held at Grosvenor House, London, from April 7 to 9th, and will be opened at 11 a.m. on April 7th by Sir Robert Renwick, President of the Radio and Electronic Component Manufacturers' Federation.

RADIOACTIVE ISOTOPES IN INDUSTRY.—The Federation of British Industries, 21, Tothill Street, London, S.W.1, has published a report of the conference on the use of radioactive isotopes in industry, which was held in May, 1951, under the auspices of the F.B.I. and the Atomic Energy Research Establishment. This report contains in a revised form the nine papers read at the conference, but omits the discussions. The first paper took the form of a general introduction by Sir John Cockcroft, and was followed by "Non-Destructive Testing and its Application in Industry," by W. S. Eastwood; "Radioactive Tracers in Industry," by J. L. Putman; "Some Applications of Labelled Organic Compounds," by Dr. W. P. Grove; "Health Precautions," by B. S. Smith; "Radioactive Isotopes in the Textile Industry," by Dr. P. S. H. Henry; "Radioactive Isotopes in the Electrical Industry," by A. M. Morgan; "Radioactive Materials in Metal Fabrication," by C. B. Fergusson, and "Future Developments," by K. Fearnside.

TOOL AND CUTTER GRINDING.—A recent publication of A. A. Jones and Shipman, Ltd., Narborough Road South, Leicester, is entitled "Tool and Cutter Grinding," which is available free of charge from the firm to all users of its machines. It is primarily intended to assist operators of Jones-Shipman tool and cutter grinders and is one of the most useful and informative books of its kind we have seen. In addition to dealing concisely with all aspects of tool and cutter grinding and the equipment used, it gives useful general notes on other forms of grinding and the care and maintenance of machines, which is essential to produce high class work.

AN AUSTRIAN TECHNICAL ASSISTANCE TEAM.—A party of fifteen representatives of Austrian Government departments and managements and trade unions concerned with the coal mining, iron and steel, and electricity industries has recently spent about ten days in this country During that time, members of the party have had discussions with officials of the Ministry of Labour, the National Coal Board and the British Electricity Authority. They have also met representatives of the Trades Union Congress and some of its constituent unions, and have visited coal mines, steel works and electricity supply undertakings. The arrangements for the tour were made by the Ministry of Labour and the British Council in conjunction with the British Embassy in Vienna, and the Austrian Productivity Centre.

ZINC-RICH PAINTS.—The corrosion committee of the British Iron and Steel Research Association has stated that the use of the term "zinc-rich paint" should be restricted to paints containing a sufficiently high percentage of zinc pigment to ensure direct electronic contact between the metallic particles in the dry paint film. There are theoretical reasons for believing that in the simplest case this will not occur unless the metallic zinc constitutes 92 to 95 per cent by weight of the dried paint film, the exact value depending on the specific gravity and other properties of the vehicle. The corrosion committee sponsored the work at the Cambridge University metallurgical laboratories, which, during the early years of the last war, led Dr. Evans and Dr. Mayne to establish the usefulness of zinc-rich paints in resisting corrosion, and the form in which they can be most effective.

THE DEVELOPMENT OF GYROSCOPES.—An interesting account of the gyroscope, tracing its early history, and leading to a description of many navigational aids employing gyroscopic principles is provided in a new version of a short booklet, entitled "The Gyroscope Through the Ages," which is published by the Sperry Gyroscope Company, Ltd., Brentford, Middlesex. The booklet is introduced by a reference to an automatic "instrument" reference enjoyed by certain flying insects, amongst them, the house-fly, whose hatteres, vibrating rod-like weights, serve in place of a spinning mass. The early pages continue by recalling the early gyroscopic toys, Foucault's experiments and the first uses of the gyroscope to establish an artificial horizon for marine navigation and for the stabilisation of ships. The early work of Dr. Elmer Sperry in this latter field is mentioned along with his work on the first gyro-compasses of 1911, which provided navigators with a directional reference not subject to magnetic variation and deviation, and which was followed later by the gyro-pilot. The work of the company in the aeronautical sphere is then described, starting with the prize-winning automatic pilot, demonstrated in 1914 by Lawrence Sperry, and followed by other patents for gyroscopically controlled bodies. Mention is made of other gyroscopic flight instruments, and of the transition from air-operated rotors to an electrical drive, and, following the introduction of the flux valve, the incorporation of the directional gyro and the magnetic compass in a single gyro-magnetic unit. The latest development mentioned is the "Zero Reader," which is capable of replacing all "blind flying" instruments by a simple two-needle indicator. The booklet concludes with a brief review of other applications, both civil and military, of gyroscopic control in conjunction with radio, radar and other electronic aids.

Personal and Business

MR. R. FISH has been appointed works manager of British Filters, Ltd., Cox Green, Maidenhead.

DR. B. K. BLOUNT, F.R.I.C., has been appointed a deputy secretary in the Department of Scientific and Industrial Research.

MR. T. A. NANSON informs us that owing to ill health he has had to relinquish his post as sales manager to Blaw-Knox, Ltd.

MR. D. M. GLENDINNING, A.M.I.C.E., F.Inst.P., has been appointed manager of the Coryton refinery of Vacuum Oil Company, Ltd.

LITHGOWS, Ltd., states that Lady Lithgow has been appointed chairman of the company and that Sir John M. Duncanson will continue to act as deputy chairman.

METROPOLITAN-VICKERS ELECTRICAL EXPORT COMPANY, Ltd., announces the appointment of Mr. H. F. Bibby, A.M.I.Mech.E., A.M.I.E.E., as manager of its American division in London.

HOOVER LTD. announces the following appointments:—Mr. G. J. Hemmings, continental sales manager; Mr. W. M. Tribute, export advertising manager; and Mr. H. K. Squires, home advertising manager.

RANSOME AND MARLES BEARING COMPANY, Ltd., Newark-on-Trent, announces the following appointments:—Mr. Ernest Belcher, director and sales manager; Mr. J. B. Samson, M.I.Mech.E., director and works manager.

THE FAIRFIELD SHIPBUILDING AND ENGINEERING COMPANY, Ltd., announces that Vice-Admiral Eric Longley-Cook, who retired recently from the post of Director of Naval Intelligence, has been appointed managing director of the company.

THE BRITISH ELECTRICITY AUTHORITY states that Mr. T. A. G. Madden, A.M.I.Mech.E., A.M.I.E.E., has been appointed engineer-in-charge of the co-ordinating sub-branch of the generation construction sub-department at headquarters.

ABOE (SCOTLAND), Ltd., has been renamed Brush ABOE (Scotland), Ltd., with registered offices at Wishaw. This company is now responsible for spares and service activities of the diesel engine factories of the Brush ABOE group. A new company, Brush ABOE (Ireland), Ltd., has been formed, with registered offices at 195, Pearse Street, Dublin, C.5.

Contracts

VICKERS-ARMSTRONGS, Ltd., has received an order to build two cargo liners, of 10,500 tons deadweight, from Ellerman Lines, Ltd. The ships will be constructed at the Naval Yard, Newcastle upon Tyne.

LOBNITZ AND CO., Ltd., has contracted to build a sludge vessel for the London County Council to replace the "G. W. Humphreys," lost through enemy action in 1940. The vessel will be 262ft long by 43ft 6in beam by 17ft 3in depth, and on a mean draught of 12ft 6in will have a displacement of 2925 tons, and carry 1560 tons of sewage sludge.

Launches and Trial Trips

WAREATEA, cargo ship; built by Henry Robb, Ltd., for William Holyman and Sons Pty., Ltd., Tasmania; length between perpendiculars 240ft, breadth moulded 37ft, depth moulded to upper deck 16ft, deadweight 1465 tons on 14ft 6in draught, trial speed 11¼ knots; Atlas Polar diesel engine, eight cylinders, 1280 b.h.p. at 250 r.p.m. Launch, February 27th.

CORNWALL, cargo liner; built by Alexander Stephen and Sons, Ltd., for the Federal Steam Navigation Company, Ltd.; length overall 489ft, breadth moulded 62ft 6in, depth moulded 40ft 3in, deadweight 9500 tons, load draught 26ft 7½in; two Stephen-Sulzer diesel engines each of 4000 s.h.p. at 225 r.p.m. drive the propeller at 100 r.p.m. through hydraulic clutches and double helical single reduction gearing, by the Power Plant Company, which delivers 7600 s.h.p. to the propeller shaft; three 235kW generators driven by British Polar diesel engines. Trial, February.

KING MALCOLM, cargo liner; built by Harland and Wolff, Ltd., for the King Line, Ltd.; length between perpendiculars 435ft, breadth moulded 59ft, depth moulded to shelter deck 39ft 9in, 5770 tons gross; seven watertight bulkheads, four main cargo holds, derricks include one of 50 tons and one of 25 tons; Harland-B. and W. single-acting, four-stroke diesel engine, six cylinders, 740mm diameter by 1500mm stroke, 115 r.p.m.; three 125-kW diesel generators. Trial: February 29th.

British Patent Specifications

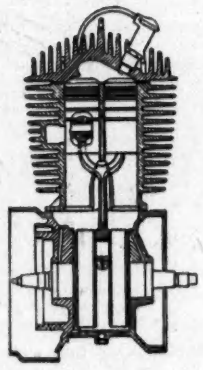
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. each.

INTERNAL COMBUSTION ENGINES

666,349. July 13, 1949.—Two-Stroke Internal Combustion Engines, Triumph Werke Nürnberg Aktiengesellschaft, of 212, Fürtherstrasse, Nürnberg, Germany.

As illustrated in the drawing, the invention concerns a two-stroke internal combustion engine, which has two cylinders divided by a partition wall and covered by a common cylinder head in which the two pistons are acted upon by a common impulse and work in the same direction in phase with each



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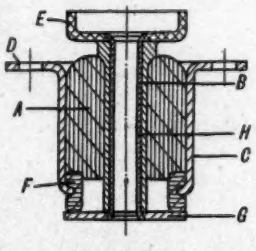
other. They are driven from a common crankshaft, and are mounted on a forked-shaped connecting-rod. The bolt holes of the piston bolts are above the lower edges of the pistons, so that over the whole of their stroke the pistons are guided in the cylinders. The partition wall is provided with slots, enabling the fork-shaped end of the connecting-rod to extend, in the inner dead centre position of the pistons, as far as possible into the cylinder spaces. The slots are so positioned that in the dead centre position they are not uncovered by the upper edges of the pistons. For air cooling the crankshaft is arranged so as to be perpendicular to the direction of the cooling air current and to the direction of motion.—*February* 13, 1952.

BEARINGS AND SUPPORTS

666,728. April 5, 1949.—Vibration Absorption Joint, Conrad Allan Cook, of F. J. Cleveland and Co., 29, Southampton Buildings, Chancery Lane, London, W.C.2 (*communicated by RIV—Officine di Villar Perosa Societa per Azioni, of* 148, *Via Nizza, Turin, Italy*).

This joint is intended for motor vehicles between the engine and frame. As shown, the joint comprises a bush *A* of rubber or similar material interposed (and



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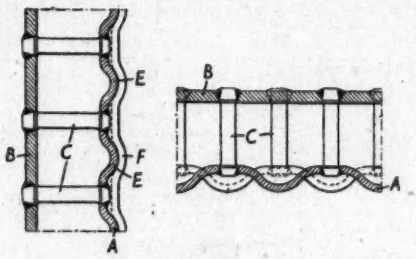
prevented from axial displacement) between an internal sleeve *B* and an outer sleeve *C*. The outer sleeve has a flange *D* and a disc *E* is provided for attachment to the associated members. The non-flanged end of the sleeve has internally attached to it a rubber ring *F* partly adhering to the bush *A*. This ring is much thinner than the bush, and partly projects from the sleeve *C*. Upon assembly, the disc *E* is submitted to a load, which is considerably lower than the operating load, and the bush is deformed as shown. A disc *G* is then secured to the sleeve *B* and adheres to the ring *F*, retaining the bush in its deformed condition after removal of the load. The sleeve *B*, disc *E* and disc *G* are held together by a tube *H* riveted at both ends on the discs. The internal sleeve *C* is enlarged at the near end of the disc *E*. The rubber bush *A* is free and is largely deformed in accordance with its natural flexibility until the action of the enlargement first and of the disc *E* next reduces flexibility, limiting the deformation of the sleeve.—*February* 20, 1952.

STEAM GENERATORS

666,757. November 22, 1949.—Preventing Breakage of Stay Bolts in Locomotives and Steam Boilers, Aktiebolaget Motala Verkstad, of Motala Verkstad, Sweden.

As shown in the drawings, *A* is the inner boiler wall and *B* the outer wall, the two being connected together by stay bolts *C*. The inner wall is provided with bulges *E* and *F* between the stay bolts. As



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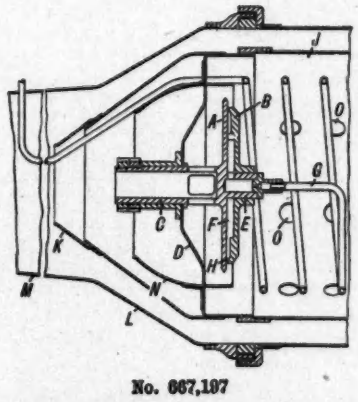
shown, the bulges are made as large as the spacing of the stay bolts will allow, and the bulges *E* located immediately between the flats for the stay bolts are smaller than the bulges centrally disposed between four flats. The bulges impart to the plate a corrugated form in which closely spaced flat areas are separated by bulges. In a boiler which is subjected to considerable heat due to the radiation of heat and/or due to flue gases, the plate has closely spaced substantially flat areas, each for accommodating one end of a stay bolt separated by bulges. The plate is thereby made capable of deformation under the action of heat without the transfer of appreciable deformation stresses to the stay bolts.—*February* 20, 1952.

BURNERS AND SPRAYERS

667,197. May 23, 1949.—Liquid Fuel Burners, Joseph Lucas, Ltd., Great King Street, Birmingham, 12. (*Inventor: John Stanley Clarke.*)

The invention describes an improved liquid fuel burner for use in the combustion chambers of jet engines and gas turbines. Referring to the drawing, the nozzle is constructed from a pair of circular metal plates *A* and *B*. The plate *A* is formed at one side with a hollow axial shank *C*, secured to a perforated supporting plate *D* at the entrance of the



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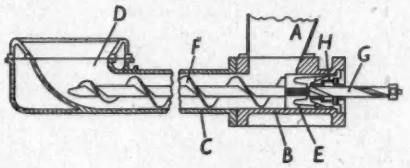
combustion chamber. At the other side it is formed with a hollow central boss *E* carrying the second plate B. The adjacent faces of the plates are shaped to form a shallow chamber *F*, to which vaporised fuel is supplied from a tube *G*. The plate *A* is of rather larger diameter than the plate *B*, and the peripheral part forms, with the adjacent face of plate *A*, a narrow annular orifice *H*, through which the vaporised fuel can flow radially from the chamber. The vaporising tube extends into the combustion chamber *J*, the supply end of the tube extending rearwards through an air duct *K* at the rear of the chamber. The combustion chamber and air duct are surrounded by an air jacket *L*, terminating in an air supply pipe *M* from which both the jacket and the duct are fed with air from a blower or other source. The plate which carries the nozzle has secured to it a bell-shaped shield *N* which at its larger end surrounds the nozzle. This duct serves to direct air into the jacket, and the air entering is divided by the part *N* into two concentric streams. The inner stream flows through *C* and plate *D* to the region around the nozzle, and the outer stream flows to the peripheral region of the combustion region in the combustion chamber *J*, where it meets with air from the jacket through perforations *O*. It is claimed that an efficient burner can be provided thus in a very simple and robust form.—*February* 27, 1952.

FURNACES AND HEATERS

666,686. August 7, 1947.—Conveying Mechanisms for Stokers, Henry Percy Baughan, Lansdown, Stroud, Gloucestershire.

Referring to the drawing, a hopper *A* is mounted over an inlet into the cylinder *B* to which is attached the feed channel *C* and the retort *D*. The ram *E* is a sliding fit in the cylinder and to its front is attached the spiral shaft *F*. To the back of the ram is attached the actuating shaft *G* which has a spiral groove formed on its periphery equal in pitch to the pitch of spiral shaft *F*. The actuating shaft is mounted in bearings; also mounted therein is a ratchet mechanism *H*, the inner member of which



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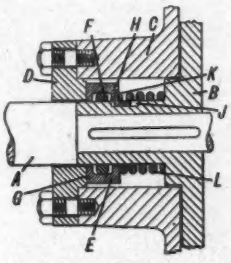
meshes with the groove on shaft *G*. This inner member is free to revolve in one direction, but is locked against rotation in the opposite direction. The ratchet mechanism is arranged so that it is free to revolve as the actuating shaft *G* is urged forward and thus no rotary motion is transmitted to the shafts *F* and *G*. When the ram is drawn back, the ratchet locks and the shaft *G*, complete with ram *E* and spiral *F*, is caused to revolve by the groove on the shaft. Thus the ram and spiral advance in a straight line and urge the fuel along the channel, but the spiral is caused to revolve, or screw itself out of the fuel, on its backward motion, leaving the fuel in its position in the channel. Another ratchet mechanism, working in the opposite direction, may be fitted to the shaft so as to prevent the shaft from rotating on its forward stroke. By this means the fuel is conveyed along its channel without crushing or grinding.—*February* 20, 1952.

SHAFT SEALS AND GUIDES

667,254. January 5, 1950.—Sealing Devices for Shafts and Rotary Members, Charles Malcolm Cherrie and Worthington-Simpson, Ltd., both of the company's address at Newark-on-Trent.

The invention is described as applied to a rotary seal construction described in the specification of 1947 (No. 632,957). It has a shaft *A* carrying a rotary element *B*, a fixed casing *C*, an attached cover *D*, and a rubbing ring *E* grooved to accommodate a compressible sealing ring *F* held against a stationary



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rubbing surface or complementary fixed face *G* on the interior of the cover *D*. The inner face of the rubbing ring *E* is formed with a radial groove or slot *H* and a short keyway or groove *J* is formed in the adjacent part of the element *B*. A key *K* in the keyway has its radially extending portion in the groove *H* in the rubbing ring. The key slides in the keyway and its radial portion is engaged by the spring *L*, which holds the rubbing ring *E* in engagement with the stationary rubbing surface. In this way the key is maintained in positive driving relation with the rubbing ring and is also prevented by the spring from being displaced under the action of centrifugal force. The arrangement is such that the rubbing ring can move slightly, whilst at all times a positive drive can be transmitted to the ring by the key. More than one key may be provided if desired.—*February* 27, 1952.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

Association of Supervising Electrical Engineers

Mon., Mar. 24th.—LUTON BRANCH: George Hotel, Luton, "Resistance Welding," H. E. J. Butler, 8 p.m.
Tues., Mar. 25th.—W. LONDON BRANCH: Windsor Castle Hotel, 134, King Street, Hammersmith, W.6, "Marine Radar," F. H. Dale, 7.30 p.m.
Fri. and Sat., Mar. 28th and 29th.—Royal Horticultural New Hall, Greycoat Street, Westminster, London, S.W.1, Electrical Engineers' Exhibition, 10 a.m. to 7 p.m.

British Institution of Radio Engineers

Thurs., Mar. 27th.—London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1, "Magnetic Amplifiers and their Applications to Industrial Processes," H. M. Gale, 6.30 p.m.

Chemical Society

Thurs., Mar. 27th.—Burlington House, Piccadilly, London, W.1, "The Chemical Exploration of the Stratosphere," F. A. Paneth, 7.30 p.m.

Cleveland Institution of Engineers

To-day, Mar. 21st.—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "The Measuring of Reheating Furnace Performance," F. A. Gray, 6.30 p.m.

Ex-British-Westinghouse Association

To-day, Mar. 21st.—Connaught Rooms, London, W.C.2, Annual Re-Union, 6 p.m.

Illuminating Engineering Society

To-day, Mar. 21st.—GLOUCESTER AND CHELTENHAM CENTRE: General Electric Co., Ltd., St. Aldate Street, Gloucester, Film Show, 6.15 p.m.
Fri., Mar. 28th.—BIRMINGHAM CENTRE: Imperial Hotel, Temple Street, Birmingham, "Light and Colour," G. J. Chamberlin, 6 p.m.
Mon., Mar. 31st.—LEEDS CENTRE: Lighting Service Bureau, 24, Aire Street, Leeds, 1, "Light and Sight," J. Benson, 7 p.m.

Incorporated Plant Engineers

Thurs., Mar. 27th.—S. YORKSHIRE BRANCH: Grand Hotel, Sheffield, Annual General Meeting, 7.30 p.m.
Fri., Mar. 28th.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, Annual General Meeting, Symposium of Films on Welding, 7.30 p.m.
Mon., Mar. 31st.—W. AND E. YORKSHIRE BRANCH: The University, Leeds, Annual General Meeting, 7.30 p.m.

Institute of British Foundrymen

Wed., Mar. 26th.—LONDON BRANCH: Waldorf Hotel, Aldwych, W.C.2, "The Buyer's Point of View," J. F. Kayser, 7.30 p.m.——BIRMINGHAM BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, "Recent Developments in Foundry Mechanisation," A. S. Beech, 7.15 p.m.
Sat., Mar. 29th.—BRISTOL AND W. OF ENGLAND BRANCH: Grand Hotel, Broad Street, Bristol, Annual General Meeting and Short Paper Prize Scheme, 3 p.m.

Institute of Industrial Supervisors

Tues., Mar. 25th.—LEICESTER SECTION: College of Technology, The Newarke, Leicester, "American Foremanship Report," H. L. Hazelgrave, 7.30 p.m.
Thurs., Mar. 27th.—GLASGOW SECTION: Royal Technical College, Glasgow, "Industrial Organisation and Administration, with special reference to Production Control," S. Waugh, 7.30 p.m.

Institute of Marine Engineers

To-day, Mar. 21st.—College of Technology, Liverpool, "Gas Turbines," A. W. Pope, 7 p.m.
Thurs., Mar. 27th.—S. E. London Technical College, Lewisham Way, London, S.E.4, "Refrigeration at Sea," R. R. Strachan, 8 p.m.

Institute of Metals

Mon., Mar. 24th.—Royal Institution, Albermarle Street, London, W.1, "The Place of Plastics in the Order of Matter," J. J. P. Staudinger, 6 p.m.
Tues., to Thurs., Mar. 25th.–27th.—Park Lane Hotel, Piccadilly, London, S.W.1, Annual General Meeting, 10a.m.
Thurs., Mar. 27th.—BIRMINGHAM LOCAL SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Extrusion," Christopher Smith, 7 p.m.

Institute of Navigation

To-day, Mar. 21st.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Navigation and the Ocean Weather Service," C. E. N. Frankcom, 5 p.m.

Institute of Petroleum

Wed., Mar. 26th.—26, Portland Place, London, W.1, "Comparison of the Fixed Bed, Liquid-Phase Slurry," and Fluidised Bed Techniques in the Fischer-Tropsch Synthesis," C. C. Hall and S. L. Smith, 5.30 p.m.

Institute of Refrigeration

Tues., Mar. 25th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park. London. S.W.1, "Non-Condensable Gases in Ammonia Plants—Their Effect and Removal," E. S. Green and J. C. E. Lowcock, 5.30 p.m.

Institute of Road Transport Engineers

Tues., Mar. 25th.—N.E. CENTRE: Dunelm Hotel, Old Elvet, Durham City, "All Metal Bodies," H. A. Cooke, 7 p.m.

Institution of British Agricultural Engineers

Tues., Mar. 25th.—Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C.2, "Development of Agricultural Tractor and Implement Tyres," M. A. Wilson, 2.15 p.m.

Institution of Chemical Engineers

To-day, Mar. 21st.—LONDON GRADUATES' AND STUDENTS' SECTION: Caxton Hall, Westminster, S.W.1, "The Design of Bubble Cap Distillation Columns," D. C. Freshwater, 6.30 p.m.
Wed., Mar. 26th.—MIDLANDS BRANCH: The University, Edmund Street, Birmingham, "Construction and Personnel Planning of the Esso Refinery, Fawley," G. Noble, 6.30 p.m.
Thurs., Mar. 27th.—N.W. CENTRE, GRADUATES' AND STUDENTS' SECTION: Queen Hotel, City Road, Chester, "The Fluid Catalytic Cracking Process." J. G. Lucas, 7 p.m.

Institution of Civil Engineers

Tues., Mar. 25th.—Great George Street, Westminster, London, S.W.1, "Buoyant Foundations in Soft Clay for Oil Refinery Structures at Grangemouth," C. W. Pike and B. F. Saurin, 5.30 p.m.
Wed., Mar. 26th.—N.W. ASSOCIATION: 9, the Temple, 24, Dale Street, Liverpool, "Coast Erosion," H. G. Nesbitt, 6 p.m.
Fri., Mar. 28th.—YORKSHIRE ASSOCIATION: Great Northern Station Hotel, Leeds, "Recent Developments in the Design of Highway Bridges in Hampshire," E. W. H. Gifford, 7 p.m.

Institution of Electrical Engineers

Mon., Mar. 24th.—RADIO SECTION: Savoy Place, London, W.C.2, "Radio-Controlled Models," 5.30 p.m.
Wed., Mar. 26th.—SUPPLY SECTION: Savoy Place, London, W.C.2, "The Design of High-Speed Salient-Pole A.C. Generators for Water Power Plants," E. M. Johnson and C. P. Holder, 5.30 p.m.
Thurs., Mar. 27th.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "The Field for College Laboratory Experiments on Modern Magnetic Materials," opened by L. G. A. Sims, 6 p.m.
Fri., Mar. 28th.—N.E. STUDENTS' SECTION: Grey Hall, King's College, Newcastle upon Tyne, "Switchgear," L. Drucquer, 6.30 p.m.
Mon., Mar. 31st.—Savoy Place, London, W.C.2, Discussion on "Statistics as Applied to Engineering," opened by W. A. Carne, 5.30 p.m.

Institution of Engineers and Shipbuilders in Scotland

Tues., Mar. 25th.—39, Elmbank Crescent, Glasgow, "Polyphase Commutator Motors," J. E. Parton, 6.30 p.m.

Institution of Mechanical Engineers

To-day, Mar. 21st.—Storey's Gate, St. James's Park, London, S.W.1, "Centrifugal Pumps in Steam Power Stations," R. Pennington, 5.30 p.m.——E. MIDLAND BRANCH: Technical College, Lincoln, "Combined Power and Process Work," A. Stewart, 7.15 p.m.——SOUTHERN BRANCH, GRADUATES' SECTION: Municipal College, Bournemouth, "Design Problems of a Refrigerated Decompression Chamber," T. V. Small, 6.30 p.m.
Mon., Mar. 24th.—N.E. BRANCH: Neville Hall, Westgate Road, Newcastle upon Tyne, "Operation of Dunston Power Station," A. Howell and J. B. Jackson-6 p.m.
Tues., Mar. 25th.—BIRMINGHAM A.D. CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Performance of Crankcase Lubricating Oils," A. Towle, 6.45 p.m.
Wed., Mar. 26th.—YORKSHIRE BRANCH: Technical College, Huddersfield, "The Design and Development of an Agricultural Tractor," H. E. Ashfield, 2.15 p.m.——LUTON A.D. GRADUATES' SECTION: George Hotel, Luton, "Design Aspects of the Internal Combustion Engine," J. E. Jesson, 7.15 p.m.——N.W. A.D. CENTRE: Grosvenor Hotel, Chester, "Factors Affecting the Utilisation of Anti-Knock Quality in Automobile Engines," J. D. Davis, 7.15 p.m.
Thurs., Mar. 27th.—N.W. BRANCH GRADUATES' SECTION: Engineers' Club, Albert Square, Manchester, "Pictorial Drawing Applied to Engineering," E. V. Scandrett, 6.45 p.m.——WESTERN A.D. CENTRE: Royal Hotel, Bristol, "Shock Absorbers," J. W. Kinchin, and C. R. Stock, 6.45 p.m.
Fri., Mar. 28th.—Storey's Gate, St. James's Park, London, S.W.1, Annual General Meeting, 5.30 p.m.

Institution of Post Office Electrical Engineers

Wed., Mar. 26th.—Conference Room, Fourth Floor, Waterloo Bridge House, London, S.E.1, "The Provincial Exchange Area—Some Aspects of its Design and Development," R. Thornton, 5 p.m.

Institution of Production Engineers

Tues., Mar. 25th.—LUTON SECTION: Town Hall, Luton, "Some Fundamentals in Press Tool Design," T. A. Stevens, 7.15 p.m.
Wed., Mar. 26th.—LINCOLN SECTION: Ruston and Hornsby, Ltd., Boultham Works, Lincoln, Annual General Meeting, 7.30 p.m.——LONDON GRADUATE SECTION: 36, Portman Square, W.1, Annual General Meeting and Film Evening, 7.15 p.m.——SHREWSBURY SECTION: Technical College, Shrewsbury, "Efficient Production Methods Applied to Iron Founding," G. W. Nicholls, 7.30 p.m.——WESTERN SECTION: Grand Hotel, Bristol, 1, Annual General Meeting, 7.15 p.m.
Thurs., Mar. 27th.—S. WALES AND MONMOUTHSHIRE SECTION: S. Wales Institute of Engineers, Park Place, Cardiff, "Relationship Between the Functions of the Production Engineer and Cost Accountant," H. J. Furness, 6.45 p.m.——CORNWALL BRANCH: Technical College, Trevenson Park, Pool, "Geophysics," T. C. Richards, 7.15 p.m.
Fri., Mar. 28th.—COVENTRY SECTION: Geisha Cafe, Hertford Street, Coventry, "Manufacture of Electric Light Bulbs," S. R. Eade, 7 p.m.——LUTON GRADUATE SECTION: Court House, St. Albans, Annual General Meeting and Film Evening, 7.30 p.m.
Mon., Mar. 31st.—SOUTHERN SECTION: Municipal College, Portsmouth, "Machining Methods at Swindon Works," W. Lynch, 7 p.m.

Institution of Structural Engineers

Thurs., Mar. 27th.—11, Upper Belgrave Street, London, S.W.1, "Unusual design for a Large Constructional Shop," F. R. Bullen, 5.55 p.m.

Institution of Water Engineers

Wed., Mar. 26th.—S.E. SECTION: Institution of Civil Engineers, Great George Street, London, S.W.1, Annual General Meeting, "Some Aspects of Valve Engineering in Water Supply," P. L. Boucher, followed by a Film, 2.30 p.m.

Junior Institution of Engineers

To-day, Mar. 21st.—39, Victoria Street, London, S.W.1, "Industrialists in the New Towns," A. S. Ladley, 6.30 p.m.
Mon., Mar. 24th.—SHEFFIELD AND DISTRICT LOCAL SECTION: Co-operative Educational Centre, 201, Napier Street, Sheffield, 11, "Snow Clearing and Frost Gritting," R. W. T. Norton, 7.30 p.m.
Fri., Mar. 28th.—39, Victoria Street, London, S.W.1, "Centrifugal Pumps," J. A. Cribb, 6.30 p.m.

Liverpool Engineering Society

Wed., Mar. 26th.—9, The Temple, 24, Dale Street, Liverpool, "Coast Erosion," H. G. Nesbitt, 6 p.m.

Manchester Association of Engineers

To-day, Mar. 21st.—Engineers' Club, Albert Square, Manchester, Annual General Meeting, "Training for Management," F. C. Lawrence, 6.45 p.m.

North-East Coast Institution of Engineers and Shipbuilders

To-day, Mar. 21st.—Mining Institute, Newcastle upon Tyne, "Modern Foundry Practice," T. W. Bushell, 6.45 p.m.

Royal Aeronautical Society

Tues., Mar. 25th.—GRADUATES' AND STUDENTS' SECTION: 4, Hamilton Place, London, W.1, Annual General Meeting, "Aerodynamic Oscillations of Suspension Bridges," C. Scruton, 7 p.m.
Thurs., Mar. 27th.—4, Hamilton Place, London, W.1, "Some Aspects of Civil Jet Aircraft Performance," D. R. Newman, 7 p.m.

Royal Society of Arts

Wed., Mar. 26th.—John Adam Street, Adelphi, London, W.C.2, "The Rolling of Ships," A. J. Sims, 2.30 p.m.

Codes of Practice

IN our issue of February 22nd last, a note was given on the code "Earth Retaining Structures," which is No. II in the Civil Engineering Codes of Practice Series. This Code is obtainable from the Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, and not from the British Standards Institution, as stated in the heading which appeared above our note.

PAINTING

The Council for Codes of Practice for Buildings has now issued in final form Code 231, "Painting." The code relates to the painting of buildings for the purposes of decoration, protection or hygiene, and includes a code dealing with general considerations and sub-codes on particular aspects of painting wood, building boards, sheets and slabs; iron and steel; non-ferrous metals; plaster, concrete, brick and stone; lime plaster; calcium sulphate plasters; Portland cement concrete, plastering and rendering; brickwork, and stone masonry. Copies may be obtained from the British Standards Institution, 24–28, Victoria Street, London, S.W.1, price 10s.

COAL IN NORTHERN IRELAND.—Supplementary estimates presented recently in the Northern Ireland Parliament included £12,500 for mineral exploration. The Minister of Commerce explained that the money was required to cover the cost of additional equipment needed to deepen a bore for coal at Mire House, near Stewartstown—which has already been taken to 3500ft—to a maximum depth of 5500ft. He stated that only one other deep bore, at Dernagh, Co. Tyrone, was in progress at present. The investigations, the Minister said, were being undertaken by the Northern Ireland branch of the Geographical Survey, and were necessary to clear up the question as to whether or not there was any workable coal in South Tyrone.